Installation Restoration Program (IRP)
Final Phase I Feasibility Study Report

143rd Combat Communications Squadron
Seattle Air National Guard Station
Washington Air National Guard
Seattle, Washington

July 1998

Air National Guard
Andrews AFB, Maryland

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Acronym	Definition
AGE	Aerospace Ground Equipment
ANG	Air National Guard
ANG/CEVR	Air National Guard/Civil Engineering Environmental Restoration Group
ANGS	Air National Guard Station
AOC	Area of concern
ARAR	Applicable or relevant and appropriate requirement
bgs	Below ground surface
CCSQ	Combat Communications Squadron
COC	Contaminant of concern
ERM	Environmental Resources Management
FS	Feasibility Study
GAC	Granular activated carbon
IRP	Installation Restoration Program
µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter
mg/L	Milligrams per liter
MTCA	Model Toxics Control Act
NFA	No Further Action
PA	Preliminary Assessment
PA/SI	Preliminary Assessment/Site Inspection
POTW	Publicly-owned treatment works
PSG	Project screening goal
RAO	Remedial action objective
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
SVE	Soil vapor extraction
TCE	Trichloroethylene

LIST OF ACRONYMS

Acronym	Definition
TPH	Total petroleum hydrocarbons
TTO	Total toxic organics
USEPA	United States Environmental Protection Agency
UST	Underground storage tank
UV	Ultraviolet
VOC	Volatile organic compound
WDOE	Washington Department of Ecology

EXECUTIVE SUMMARY

As part of the Department of Defense Installation Restoration Program used to investigate potentially contaminated sites on Air National Guard property, Environmental Resources Management conducted a Feasibility Study (FS) for the Washington Air National Guard's Seattle Air National Guard Station (Seattle ANGS) site. The Seattle ANGS is located on a 7.5-acre parcel of land in the northwest portion of the King County International Airport (Boeing Field) in Seattle, Washington.

As discussed in the Phase I Remedial Investigation (RI) report (ERM, 1998a), trichloroethene (TCE) in groundwater at relatively low concentrations is the only contaminant of concern that has been identified to date at the Seattle ANGS. This Phase I FS report presents a number of potential remedial alternatives for addressing TCE in site groundwater, and evaluates each alternative with respect to relative effectiveness, implementability, and cost.

The FS is incomplete at this time due to an incomplete characterization of the subject site. It is recommended that additional investigative work be conducted to identify a potential source of the TCE and to further evaluate concentrations of TCE relative to applicable or relevant and appropriate requirements. A Phase II RI is planned for the site during Summer 1998. Work that remains to be done on the FS includes further definition, screening, and detailed analysis of the remedial alternatives presented in this Phase I report. The five alternatives requiring further definition and detailed analysis are:

- No Action. No action will be taken.

- Limited Action/Institutional Controls/Natural Attenuation. Includes groundwater monitoring for volatile organic compounds and restrictions on future groundwater use and/or land use. Also includes optional natural attenuation monitoring as necessary to justify no further action.

- Groundwater Extraction/Disposal. Includes groundwater extraction followed by disposal to the sanitary sewer.

- Groundwater Extraction/Ex-Situ Treatment/Disposal. Includes groundwater extraction, removal of TCE by carbon adsorption treatment, and disposal of treated groundwater to the sanitary sewer or discharge to infiltration trenches.

- In-Situ Groundwater Treatment. Includes air sparging to volatilize the TCE and/or methanogenic co-metabolism to enhance biodegradation of the TCE.

The results of the final screening and detailed analysis of the remedial alternatives will be presented in the Phase II Remedial Investigation/Feasibility Study report, to be prepared following completion of the Phase II RI field work.

SECTION 1.0

INTRODUCTION

This Phase I Feasibility Study (FS) report has been prepared for the Seattle Air National Guard Station (Seattle ANGS) site in Seattle, Washington. The FS was conducted as part of the Air National Guard (ANG) Department of Defense Installation Restoration Program (IRP) under Contract DAHA90-94-0014, Delivery Order 0032. The Air National Guard/Civil Engineering Environmental Restoration Group (ANG/CEVR) provided technical and project management oversight for this study on behalf of the ANG. This FS report follows the recommended ANG/CEVR format and contains the basic contents suggested in the United States Environmental Protection Agency (USEPA) document *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988).

As discussed in the Phase I Remedial Investigation (RI) report (ERM, 1998a), trichloroethylene (TCE) in groundwater is currently the only contaminant of concern (COC) that has been identified at the Seattle ANGS. TCE was detected at a concentration greater than two times the associated Washington State Model Toxics Control Act (MTCA) Method A Cleanup Level in a Geoprobe/HydroPunch groundwater sample collected in the southern portion of the Station. Subsequent groundwater monitoring has not confirmed the presence of TCE at concentrations greater than the MTCA Method A Cleanup Level in groundwater, and a source of volatile organic compounds (VOCs) has not been identified. Additional investigative work to complete the soil and groundwater characterization at the site is proposed for Summer 1998 (ERM, 1998b).

In order to simplify the FS process, a modified focused FS format is used (USEPA, 1993). The technologies and alternatives evaluated are weighted toward those that are consistent with the Washington State Department of Ecology's (WDOE) preference for technologies that reduce mass, volume, or toxicity as stated in the MTCA Cleanup Regulation, Washington Administrative Code, Chapter 173-340 (WDOE, 1996).

1.1 Purpose and Organization of Report

The purpose of this FS report is to describe the development, screening, and detailed analysis of remedial alternatives for contaminated media identified at the Seattle ANGS. The objectives of the FS are to:

- Develop, screen, and evaluate remedial alternatives for addressing TCE-impacted groundwater at the Station that may pose a threat to human health or the environment; and
- Recommend the most cost-effective remedial alternatives that adequately protect human health, welfare, and the environment.

The Phase I Remedial Investigation/Feasibility Study (RI/FS) Work Plan (ERM, 1996) indicated that a focused FS approach would be applied if site conditions were favorable, and that the focused FS would contain the elements outlined in the USEPA guidance titled *Presumptive Remedies: Policy and Procedures* (USEPA, 1993). The modified focused FS presented here is more comprehensive than outlined in the USEPA guidance. The reason for this is that USEPA presumptive remedies are currently available only for ex-situ groundwater remediation technologies, whereas containment and in-situ remediation technologies are potentially applicable to the Seattle ANGS.

This FS report begins with a brief overview of the site history and results of the Phase I RI, followed by the development, screening, and analysis of remedial alternatives. The contents of the sections are as follows:

- Section 1.0 presents background information for the Seattle ANGS, including site location and history.
- Section 2.0 presents the remedial action objectives and the general response actions to be considered. Remediation technologies applicable to TCE contamination in groundwater are also identified and screened in this section.
- Section 3.0 presents the potential remedial alternatives developed for the Seattle ANGS.
- Section 4.0 describes the seven criteria that will be used to evaluate the remedial alternatives during the detailed analysis phase of the FS. Before a detailed analysis can be completed, additional site characterization data are needed for further definition of the alternatives. The detailed analysis of alternatives will be presented in the Phase II RI/FS report.

- Section 5.0 presents the conclusions of the study and recommendations for additional work.
- Section 6.0 lists references.

Appendices to this report include the following:

- Appendix A: Geologic cross sections from the Phase I RI;
- Appendix B: Hydrogeologic data from the Phase I RI;
- Appendix C: Phase I RI sampling locations and analyses; and
- Appendix D: Tables summarizing the identification of COCs at the Seattle ANGS.

1.2 Background Information

The Seattle ANGS is at 6736 Ellis Avenue South in Seattle, Washington (Figure 1-1). The Station occupies approximately 7.5 acres of land in the northwest portion of the King County International Airport.

1.2.1 Site Description

One area of concern (AOC) has been defined to date. The AOC, designated as IRP Site 1 - Burial Site (the IRP site), is in the northeast corner of the Station (Figure 1-2). The IRP site is approximately 175 feet long by 175 feet wide. The north and east sides of the IRP site are bounded by a 6-foot-high fence, and the site is covered with asphalt with the exception of the grass-covered northeast corner. The entire Station is surrounded by a chain-link fence to restrict site access.

The following text presents selected site information from the Phase I RI report (ERM, 1998a). A more detailed description of each topic is found in the RI report.

1.2.1.1 *Land Use*

The Seattle ANGS is zoned for industrial use. Properties to the north, east, and south have historically been used for industrial purposes and are zoned for industrial use. Property to the west of the site (across Ellis Avenue South) is residential.

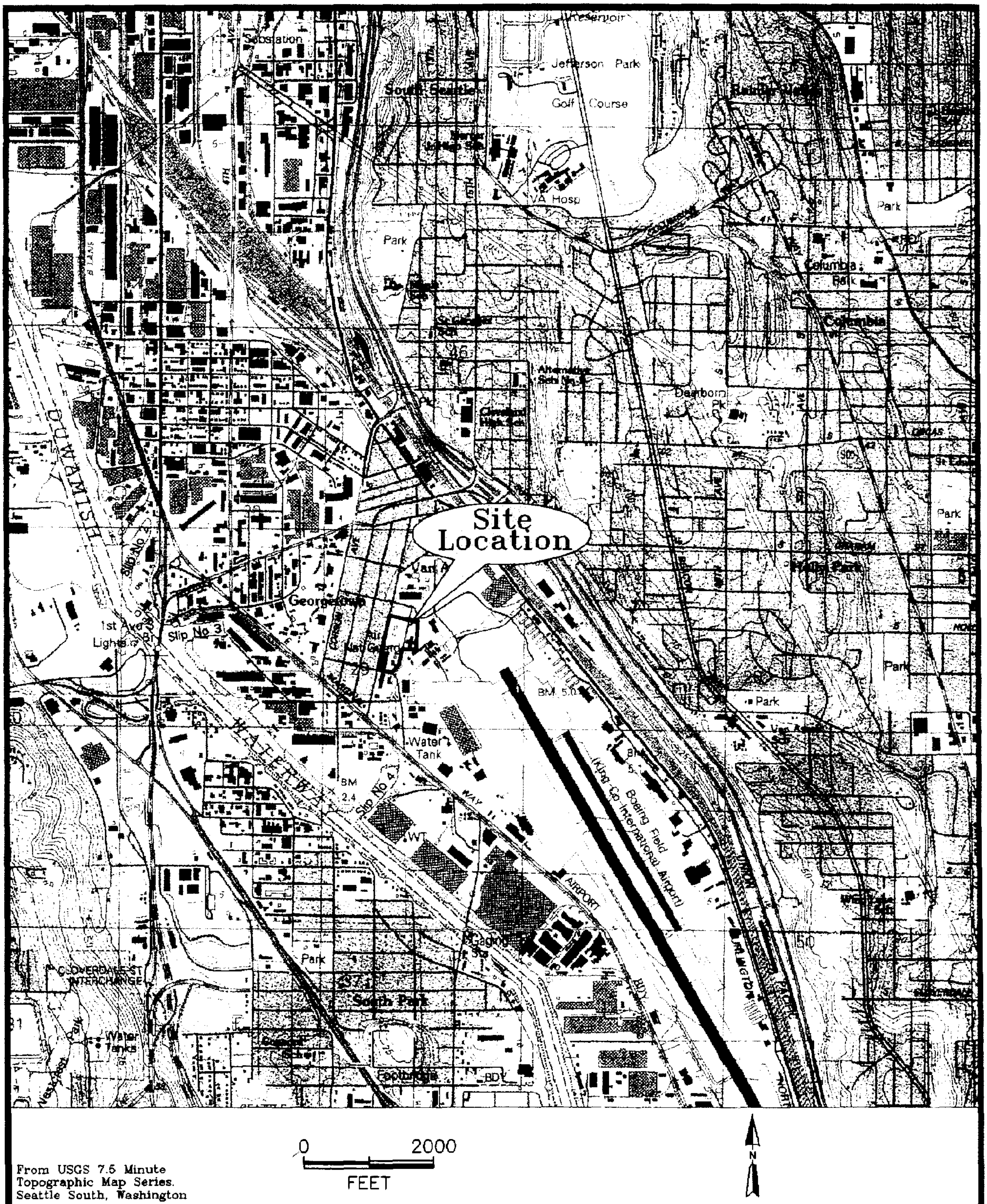

FIGURE 1-1

LOCATION MAP OF SEATTLE
AIR NATIONAL GUARD STATION
SEATTLE, WASHINGTON
143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

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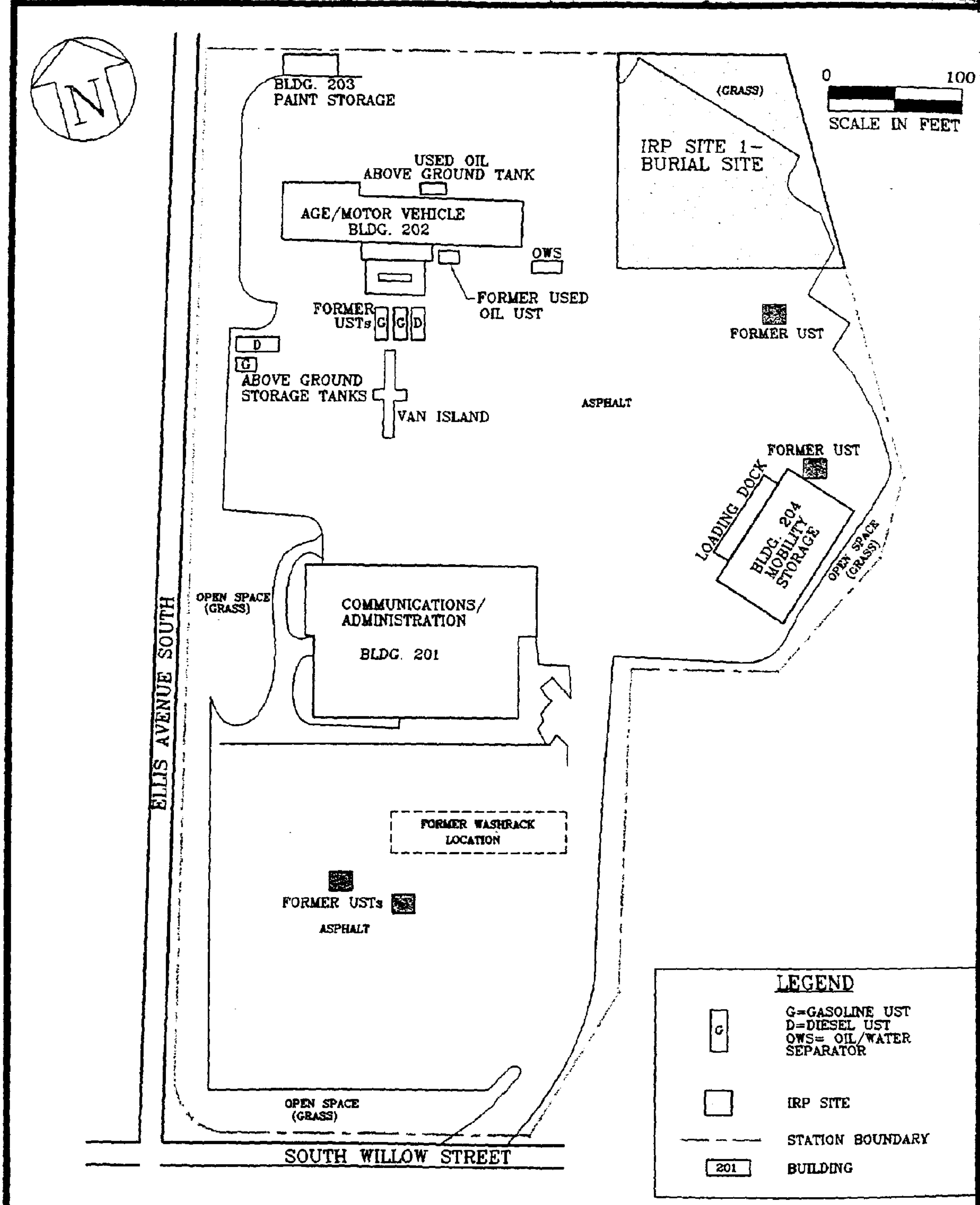

FIGURE 1-2

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SITE PLAN

143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

1.2.1.2 Topography

The Seattle ANGS is located in King County in the Puget Sound Lowlands physiographic province. The Station is on flat, level terrain with a surface elevation of approximately 7 feet above mean sea level.

1.2.1.3 Climate

The climate in the Seattle area is characterized by mild summers and cool winters, with long spring and fall seasons. The average daily temperature ranges from 37 to 47 degrees Fahrenheit (°F) in the winter and from 55 to 72°F in the summer.

The average annual precipitation is 38.84 inches, including 7.4 inches of snow. The greatest percentage of rainfall occurs from November to January. Free water surface evaporation in the Seattle area is approximately 25 inches per year, resulting in a net precipitation of 13.84 inches per year.

Prevailing wind is from the southwest, and the highest average wind speed of 9.8 miles per hour occurs in March.

1.2.1.4 Sensitive Receptors

There are no City of Seattle Water Department municipal wells within 4 miles of the Seattle ANGS, no private drinking water wells within 1 mile of the Station, and the surrounding population obtains drinking water from municipal sources.

There are no critical habitats or endangered or threatened species identified within 4 miles of the Seattle ANGS.

1.2.1.5 Site Geology

The near-surface geology at the Seattle ANGS is predominantly composed of two units. The first unit is a silty sand fill material present to a depth of approximately 8 feet below ground surface (bgs). The fill material is consistent with the descriptions of the material used to raise the Duwamish Valley for development in the 1910s. The second unit consists primarily of a well-sorted, fine-grained sand (river alluvium) and is present from approximately 8 feet bgs to 21.5 feet bgs, the maximum depth of borings drilled during the Preliminary Assessment/Site Inspection (PA/SI) and Phase I RI. Details regarding site geology are provided in the RI report. Geologic cross-sections from the RI report are provided in Appendix A.

1.2.1.6 Local Hydrogeology

Groundwater exists in an unconfined aquifer at a depth of 6 to 10 feet bgs, within the upper part of the recent river alluvium and the lower portion of the silty sand fill unit. The inferred groundwater flow direction is to the south at a gradient of 0.002 feet per foot, toward the Duwamish Waterway. The depth to groundwater is influenced by seasonal precipitation; this influence is illustrated by an approximate 2-foot increase in groundwater elevation between October 1996 and January 1997 (Appendix B).

Slug tests conducted at monitoring well MW-3 generated hydraulic conductivity estimates of 1.25×10^{-4} to 6.09×10^{-4} feet per second, which are consistent with the predominant sand lithology observed in the shallow aquifer. Monitoring well construction data, groundwater elevation data, and representative potentiometric contour maps are provided in Appendix B. A detailed hydrogeologic description is provided in the RI report.

1.2.2 Site History

The Seattle ANGS was constructed during World War II by the War Department and used by the Army and Air Force as an "Aircraft Factory School." In 1948, the property was given to King County as surplus property and was subsequently leased to the Washington ANG. The initial property was 17 acres and included 15 buildings, all of which were subsequently demolished. The squadron stationed at the Seattle ANGS went through several name changes and duty assignments. In 1988, the Seattle ANGS squadron acquired its current name, the 143rd Combat Communications Squadron (CCSQ). The 143rd CCSQ provides mobile communication support and telephone/teletype support for airports and airfields.

The Seattle ANGS currently houses four buildings: the Paint Storage Building, Aerospace Ground Equipment (AGE)/Motor Vehicle Building, Mobility Storage Building, and Communications/Administration Building (Figure 1-2). Other site features include miscellaneous above-ground storage tanks; a van island; an oil/water separator; and a former washrack and former underground storage tanks (no longer present).

Solid wastes generated from the 1950s through 1968 at the AGE/Motor Vehicle Maintenance Building, Power Production Building, and Communication/Administration Building were reportedly either burned and/or buried at the IRP site or disposed of off-site. Wastes generated during this time period included radio tubes, solvents, waste motor oils, kerosene, batteries, brake fluid, spray paints, paint thinners/removers, methyl ethyl ketone, xylene, and naphtha.

Presently, hazardous wastes are collected and disposed of by a licensed contractor or through the Defense Reutilization and Marketing Office at Fort Lewis, Washington.

1.2.3 Previous Investigations

Three IRP investigations have been conducted at the Seattle ANGS:

- A Preliminary Assessment (PA) was conducted by the ANG in December 1993.
- A PA/SI was conducted by Operational Technologies Corporation in 1994.
- A Phase I RI was conducted by Environmental Resources Management in 1996 and 1997.

The PA focused on the identification and evaluation of historic and current use, handling, and disposal practices of hazardous materials and hazardous waste at the Seattle ANGS. Based on the results of the PA, an AOC (subsequently designated IRP Site 1 - Burial Site) was identified as being potentially contaminated with hazardous materials/waste, warranting further IRP investigation.

The focus of the PA/SI was to identify AOCs and to confirm the presence or absence of soil and groundwater contamination associated with past hazardous material and hazardous waste handling and disposal practices. Field activities associated with the PA/SI included screening and confirmation activities. The screening activities included a soil vapor survey, a ground-penetrating radar survey, and a magnetometer survey at the IRP site. Confirmation activities at the IRP site included the collection of soil samples from three soil borings and one monitoring well boring and the installation and sampling of three groundwater monitoring wells. Constituents detected at concentrations above MTCA cleanup levels and/or site-specific background concentrations include total petroleum hydrocarbons (TPH) in soil, gross alpha and gross beta radiation in soil and groundwater, and metals in groundwater.

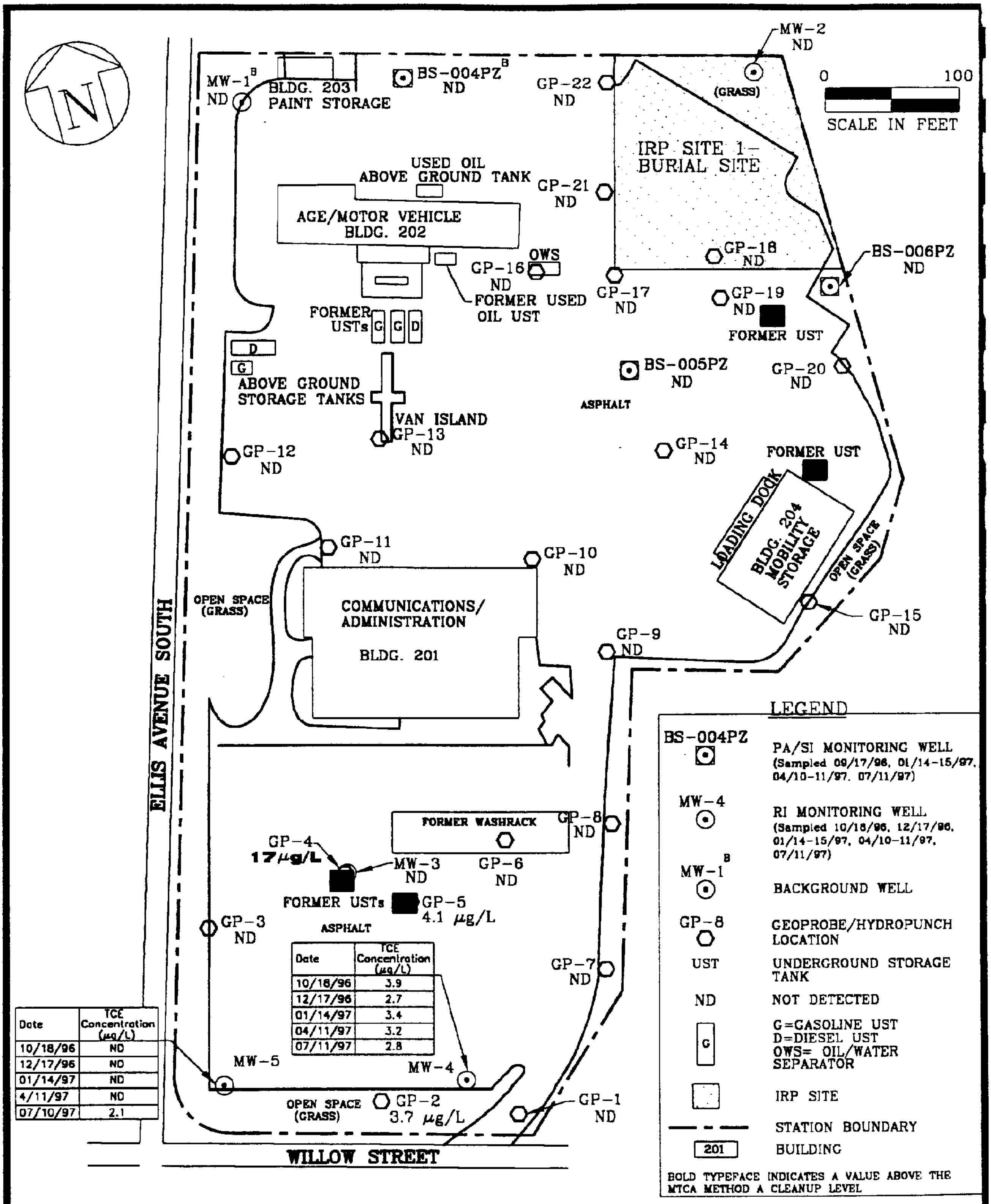
The focus of the Phase I RI was to determine the nature and extent of contamination associated with the IRP site. Field activities conducted for the RI included field screening activities and confirmation activities. The field screening activities included organic vapor screening and TPH screening of soil samples. Confirmation activities included the collection and analysis of 22 Geoprobe/HydroPunch groundwater samples, 10 surface soil samples, 2 storm sewer catch basin samples, and subsurface soil samples from 11 soil borings. Additional activities included the installation of five groundwater monitoring wells, quarterly sampling of the RI and PA/SI monitoring wells for 1 year, and aquifer slug tests to estimate hydraulic conductivity. Sampling location maps and a summary of samples collected and analyses conducted as part of the Phase I RI are provided in Appendix C. Complete analytical testing results are presented in the RI report (ERM, 1998a).

Project screening goals (PSGs) were developed during the RI for use in identifying COCs in soil and groundwater. The PSGs were derived from applicable or relevant and appropriate requirements (ARARs). PSGs for each constituent detected during the Phase I RI are listed in Appendix D, along with tables that summarize the screening process used to identify COCs. As shown in Appendix D, TCE in groundwater is the only confirmed COC identified to date at the Seattle ANGS.

1.2.4 Nature and Extent of Contamination

TCE has been detected in groundwater samples collected in the vicinity of the former washrack and two former underground storage tanks (USTs) in the southern portion of the Station. The groundwater samples were collected as part of the Phase I RI Geoprobe/HydroPunch study and groundwater monitoring program. The RI results for TCE in groundwater are summarized in Appendix C and depicted on Figure 1-3. TCE was detected in Geoprobe/HydroPunch samples GP-4 and GP-5 at concentrations of 17 and 4.1 micrograms per liter (μg/L), respectively. TCE also was detected in five groundwater samples collected from monitoring well MW-4 at concentrations ranging from 2.7 to 3.9 μg/L, and in the most recent groundwater sample collected from monitoring well MW-5 at a concentration of 2.1 μg/L. None of the groundwater samples collected from monitoring wells during the Phase I RI contained TCE concentrations exceeding the MTCA Method A Cleanup Level of 5 μg/L.

Two soil samples collected during the Phase I RI were submitted for VOC analysis. TCE was detected at a concentration of 170 micrograms per kilogram (μg/kg) in the soil sample collected at 9 feet bgs from the boring for monitoring well MW-3; TCE was not detected in the sample collected at 5 feet bgs from the same boring.



MW-5:

Date	TCE Concentration (µg/L)
10/18/96	ND
12/17/96	ND
01/14/97	ND
4/11/97	ND
07/10/97	2.1

MW-4:

Date	TCE Concentration (µg/L)
10/18/96	3.9
12/17/96	2.7
01/14/97	3.4
04/11/97	3.2
07/11/97	2.8

FIGURE 1-3

TRICHLOROETHYLENE IN GROUNDWATER

143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

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1.2.5 Contaminant Fate and Transport

The fate and transport of TCE, as discussed in the RI report, is summarized as follows. The primary route of migration for TCE at the Seattle ANGS is assumed to be transport in groundwater. In general, fate and transport of TCE in groundwater is controlled by its affinity for organic carbon constituents in soil, rates of biodegradation and biokinetic decay, and the solubility-based diffusive dilution of the compound in the aquifer. Transport of TCE in groundwater is expected to be impeded by its affinity for organic constituents in soil and its tendency to volatilize, and to a lesser degree by natural degradation processes. Degradation of TCE through aerobic, anaerobic, or abiotic processes at the Seattle ANGS is difficult to assess based on the available data.

1.2.6 Baseline Risk Assessment

A preliminary baseline risk assessment was conducted as part of the Phase I RI to evaluate the potential for TCE to cause adverse health effects in exposed individuals via ingestion of TCE-contaminated drinking water and inhalation of its vapors. The estimated cancer risk associated with the highest observed TCE concentration in groundwater (17 µg/L) is 2.14×10^{-6} (ERM, 1998a). This exceeds the WDOE acceptable cancer risk level of 1×10^{-6} for individual hazardous substances.

SECTION 2.0

IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.1 Introduction

This section discusses remedial action objectives (RAOs) and general response actions, and identifies potentially applicable technologies for remediation of TCE in groundwater at the Seattle ANGS. The remediation technologies are then screened using criteria of effectiveness, implementability, and cost. Technologies that are retained at the end of this section are carried over to Section 3.0 for development and screening of remedial alternatives.

2.2 Remedial Action Objectives

Section 1.0 summarized the current understanding of the nature and extent of contamination at the Seattle ANGS. The Phase I RI results suggest that, due to the presence of dissolved VOCs, groundwater at the Station poses an unacceptable risk to human health under the reasonable maximum exposure scenario assumptions of MTCA (i.e., site groundwater used as drinking water). To mitigate these potential health risks and ensure protection of groundwater resources, site-specific RAOs have been developed. These RAOs serve as the performance objectives for groundwater remediation at the Station.

RAOs are based on risk-based State and Federal numeric ARARs. RAOs for cleanup actions at the Seattle ANGS are as follows:

- Prevent or eliminate off-site migration of TCE at concentrations exceeding the MTCA Method A Cleanup Level of 5 μg/L; and

- Prevent the ingestion of groundwater exceeding the MTCA Method A Cleanup Level of 5 μg/L.

2.3 General Response Actions

The general response actions developed for remediation of groundwater at the Seattle ANGS are listed on Table 2-1 and include:

- No Action;
- Limited Action;
- Containment;
- Groundwater Extraction; and
- Ex-Situ or In-Situ Groundwater Treatment.

Consideration of the No Action response is a required component of the FS process as it provides a baseline for comparison. Limited action includes measures taken to limit human exposure to contamination other than remediation. Containment, extraction, and treatment actions include measures that will reduce the toxicity, mass, and/or volume of TCE-impacted groundwater.

For the purpose of this Phase I FS, the groundwater volume to which response actions may be applied is assumed to be 230,000 gallons. This estimate was derived from the Phase I RI site characterization data.

2.4 Identification and Screening of Technology Types and Process Options

The general response actions listed in Section 2.3 are further broken down by remediation technology type and process options on Table 2-1. Technologies and/or process options determined to be inappropriate based on criteria of effectiveness, implementability, and cost are eliminated from further consideration. The rationale for retaining or eliminating particular process options is summarized on the table.

As shown on Table 2-1, a number of different process options are retained for further consideration. Most of the process options are effective and implementable. Some of the options are eliminated as being more costly or less effective than others. Based on the screening summarized on Table 2-1, the following process options are retained for the development of remedial alternatives:

FINAL

TABLE 2-1

Response Actions and Technology Screening for Trichloroethylene in Groundwater
143rd CCSQ, Seattle ANGS, Seattle, Washington

Response Action	Remediation Technology Type	Process Option	Description	Retain?	Reasons	Comments
No Action	No Action	None	No institutional controls or treatment.	Yes	Required	Baseline for comparison.
Limited Actions	Institutional Controls	Property/Water-Use Restrictions or Notifications	Limits future property and/or groundwater use through legal means (e.g., deed restrictions).	Yes	1, 2, 3	Conservative approach - may be unnecessary since site anticipated to be an industrial facility for the long term.
		Fencing	Fencing or other means of limiting site access.	No	B	Perimeter fence already in place; additional fencing unnecessary. Also, limited effectiveness/utility for groundwater contamination.
		Signs	Signs or other means of warning potential trespassers or site users of potential dangers.	No	B	Limited effectiveness/utility for groundwater contamination.
		Groundwater Monitoring	Includes regular monitoring of groundwater to evaluate effectiveness in protecting the environment.	Yes	1, 3	Easy to implement.
	Natural Attenuation	Natural Attenuation Monitoring	Includes monitoring for natural attenuation parameters to evaluate processes such as biodegradation, abiotic transformation, sorption, and dilution that may lead to reductions in groundwater VOC concentrations.	Yes	1, 3	The presence of TCE degradation products in Phase I RI groundwater samples suggests that this is a viable process option for the site.
Containment Actions	Capping	Asphalt/Concrete	Cover source area(s) with asphalt or concrete to limit infiltration of precipitation and contaminant leaching in the vadose zone.	No	See Comments	Site already paved with asphalt; additional capping unnecessary.
	Physical Barrier	Slurry Wall	Placement of a relatively impermeable vertical barrier to restrict groundwater flow and contaminant migration in the downgradient direction.	No	C	Costly and not expected to reduce the mass, volume, or toxicity of TCE.
Groundwater Extraction Actions	Pumping	Extraction Wells	Use of groundwater extraction wells to pump groundwater out of the aquifer for subsequent disposal with or without treatment.	Yes	1, 2, 3	Groundwater extraction can also create a hydraulic barrier to limit migration of contaminants.
		Extraction Trench	Use of groundwater extraction trenches to pump groundwater out of the aquifer for subsequent disposal with or without treatment.	No	C	The use of trenches for groundwater extraction is not warranted at this site given the relatively low pumping volumes required.

TABLE 2-1 (Continued)

Response Actions and Technology Screening for Trichloroethylene in Groundwater
143rd CCSQ, Seattle ANGS, Seattle, Washington

Response Action	Remediation Technology Type	Process Option	Description	Retain?	Reasons	Comments
Ex-Situ Groundwater Treatment Actions	Physical	Air Stripping	Water flowing countercurrent to air flow results in the transfer of VOCs from the aqueous phase to the air phase.	No	C	Air stripping expected to be more costly than granular activated carbon.
	Chemical and Physical	Carbon Adsorption	Water is passed through vessels containing granular activated carbon (GAC). Organic compounds with an affinity for carbon are transferred from the aqueous phase to the solid phase by sorption to the GAC.	Yes	1, 2	GAC removal of TCE is a proven technology. This technology is expected to be the most cost effective for the low concentration/low flow conditions anticipated.
	Chemical	Ultraviolet (UV)/Oxidation	UV light and/or oxidizing chemicals (e.g. hydrogen peroxide) can be used to destroy organic constituents.	No	C	UV/oxidation expected to be more costly than GAC.
	Biological	Contact Beds	Water is passed through a reactor vessel that contains a fixed bacterial film. Contaminants are destroyed by the bacteria as the water passes through the reactor vessel.	No	A, C	The retention time for TCE destruction is expected to be on the order of hours.
In-Situ Groundwater Treatment Actions	Physical	Air Sparging/Soil Vapor Extraction	Injection of air to volatilize and/or enhance biodegradation of VOCs. This technology is usually combined with soil vapor extraction for control of injected air and removal of volatiles.	Yes	1, 2	Results in permanent mass reduction of VOCs.
	Biological	Co-Metabolic Bioremediation	Injection of air and methane to enhance methanogenic degradation. TCE is degraded by enzymes produced for oxidation of the methane.	Yes	1, 2	Results in permanent mass reduction of VOCs.
	Chemical	Passive Treatment Wall	A permeable reaction wall is installed across the flow path of a contaminant plume. For TCE, the wall can be filled with iron filings which results in the oxidation of TCE. May also be installed in a "funnel and gate" layout.	No	C	More costly than air sparging or co-metabolic bioremediation.
Discharge Actions	On-Site Discharge	Subsurface Injection/Infiltration	Discharge of treated groundwater back into the subsurface through injection wells or infiltration galleries.	Yes	1, 2, 3	Re-injection of treated groundwater preserves the resource. Can be used to enhance hydraulic containment and/or vadose-zone soil flushing.
	Off-Site Discharge	Publicly Owned Treatment Works (POTW)	Discharge of treated or untreated extracted groundwater to the sanitary sewer for conveyance to the local POTW.	Yes	1, 2, 3	Expected to be the most cost-effective option if discharge meets POTW requirements.

TABLE 2-1 (Continued)

Response Actions and Technology Screening for Trichloroethylene in Groundwater
143rd CCSQ, Seattle ANGS, Seattle, Washington

Response Action	Remediation Technology Type	Process Option	Description	Retain?	Reasons	Comments
Discharge Actions (cont'd)	Off-Site Discharge (cont'd)	Storm Drain	Discharge of treated groundwater to the storm drain.	No	A, C	Requires a National Pollutant Discharge Elimination System permit. Not a "regulatory-friendly" option.

Key to reasons for retaining or rejecting a process option:

1. Implementable/Technically Feasible
2. Effective
3. Cost Effective

A. Not Implementable
B. Not Effective
C. Too Costly

GAC = Granular activated carbon
POTW = Publicly owned treatment works
TCE = Trichloroethylene
UV = Ultraviolet
VOC = Volatile organic compound
RI = Remedial Investigation

- Property/water-use restrictions or notifications;
- Groundwater monitoring;
- Natural attenuation monitoring;
- Groundwater extraction from wells;
- Granular activated carbon (GAC) treatment of extracted groundwater;
- Off-site discharge of untreated or treated extracted groundwater to the sanitary sewer;
- On-site discharge of treated extracted groundwater through underground injection wells or infiltration galleries;
- In-situ treatment by air sparging; and
- In-situ treatment by co-metabolic bioremediation.

SECTION 3.0

DEVELOPMENT AND SCREENING OF ALTERNATIVES

In this section, the remediation technologies and process options that remain following the initial screening process presented in Section 2.0 are combined to form potential remedial alternatives. These alternatives are designed to address the affected groundwater at the Seattle ANGS and/or the significant pathways of potential contaminant migration. The objective of this step is to develop remedial alternatives that protect human health and the environment and encompass a variety of response options, including:

- Control of potential exposure pathways;
- Reduction of the contaminant mass in groundwater;
- Reduction of risk to an acceptable level and prevention of potential off-site migration; or
- Some combination of the above.

Normally in an FS, potential remedial alternatives are first developed and then eliminated from further consideration if they:

1. Do not effectively protect human health and the environment (effectiveness criterion);
2. Are problematic with respect to technical or administrative feasibility (implementability criterion); or
3. Are significantly higher in cost than other alternatives without a corresponding increase in benefit, protection, or reliability (cost criterion).

Screening of potential alternatives using the above criteria typically results in a smaller, more manageable set of the most appropriate alternatives which are then further evaluated during the detailed analysis phase of the FS (Section 4.0). Because the RI site characterization has not yet been completed, none of the potential remedial alternatives presented are eliminated from further consideration.

3.1 Development of Alternatives

Five potential alternatives for groundwater remediation were developed using the technologies and process options that remained after the initial screening (Table 2-1). These alternatives are based on the current understanding of the distribution of VOCs in groundwater at the Seattle ANGS. The five remedial alternatives are outlined below and summarized on Table 3-1.

- Alternative GW-1: No Action. This alternative would leave the site in its present condition. No actions would be taken to monitor groundwater, prevent human contact, prevent contaminant migration, or mitigate the contaminants.
- Alternative GW-2: Limited Action/Institutional Controls/Natural Attenuation. This alternative includes continued groundwater monitoring for VOCs and/or restrictions on future use of the property or groundwater (e.g., deed restrictions). It also includes optional natural attenuation monitoring as appropriate to meet State requirements for no further action.
- Alternative GW-3: Groundwater Extraction/Disposal. This alternative includes groundwater monitoring, extraction of groundwater, and appropriate disposal of untreated groundwater.
- Alternative GW-4: Groundwater Extraction/Ex-Situ Treatment/Disposal. This alternative includes groundwater monitoring, extraction of groundwater, aboveground treatment, and appropriate disposal of treated groundwater.
- Alternative GW-5: In-Situ Groundwater Treatment. This alternative includes groundwater monitoring and air sparging with soil vapor extraction and/or co-metabolic bioremediation.

3.2 Screening of Alternatives

This section describes the potential remedial alternatives outlined above and evaluates each alternative with respect to criteria of effectiveness, implementability, and cost. The factors considered for each of these screening criteria include:

TABLE 3-1

Summary of Potential Alternatives for Groundwater Remediation
143rd CCSQ, Seattle ANGS, Seattle, Washington

Response Action	Remediation Technology Type	Process Option	Remedial Alternative*				
			GW-1	GW-2	GW-3	GW-4	GW-5
No Action	No Action	None	X				
Limited Actions	Institutional Controls	Property/Water-Use Restrictions or Notifications		X			
		Groundwater Monitoring		X	X	X	X
	Natural Attenuation	Natural Attenuation Monitoring		X (a)	X (a)	X (a)	X (a)
Groundwater Extraction Actions	Pumping	Extraction Wells			X	X	
Ex-Situ Groundwater Treatment Actions	Chemical and Physical	Carbon Adsorption				X	
In-Situ Groundwater Treatment Actions	Physical	Air Sparging/Soil Vapor Extraction					X
	Biological	Co-Metabolic Bioremediation					X
Discharge Actions	On-Site Discharge	Subsurface Injection/Infiltration				X	
	Off-Site Discharge	Publicly Owned Treatment Works			X	X	

*Remedial Alternatives:

GW-1 = No Action
GW-2 = Limited Action/Institutional Controls/Natural Attenuation
GW-3 = Groundwater Extraction/Disposal
GW-4 = Groundwater Extraction/Ex-Situ Treatment/Disposal
GW-5 = In-Situ Treatment

(a) = Natural attenuation monitoring is an optional component of Alternatives GW-2 through GW-5.

- Effectiveness
    - Protection of human health and the environment
    - Compliance with the RAOs
    - Reduction in toxicity, mobility, and volume through treatment
- Implementability
    - Technical feasibility
    - Availability of technology and expertise
    - Administrative approval
- Cost
    - Capital costs
    - Operation and maintenance costs

Table 3-2 summarizes the screening evaluation of the potential alternatives.

3.2.1 Alternative GW-1: No Action

Description. The No Action alternative assumes that no site modifications or groundwater monitoring would be required to prevent or eliminate human health and environmental risks associated with TCE in groundwater. A "No Further Action" (NFA) ruling would be pursued for the Seattle ANGS.

Evaluation. The No Action alternative is a required component of the FS process. Although this alternative is normally not discussed as a preferred alternative, results of the Phase I RI indicate that an NFA ruling may be appropriate at this site. This alternative meets the criteria of effectiveness, implementability, and cost, and is therefore retained for further evaluation.

TABLE 3-2

Screening Evaluation of Potential Alternatives for Groundwater Remediation
143rd CCSQ, Seattle ANGS, Seattle, Washington

Alternative	Description	Retain ?	Reasons	Comments
GW-1	No Action	Yes	Required	This alternative is carried through the FS process as a baseline for comparison to other remedial alternatives. It is also retained because concentrations of VOCs requiring response actions may not be confirmed during the Phase II RI.
GW-2	Limited Action/Institutional Controls/Natural Attenuation	Yes	1, 2, 3	This alternative is retained due to the incomplete characterization of VOCs in site soil and groundwater. Based on the Phase II RI results, continued groundwater monitoring, natural attenuation monitoring, and/or deed restrictions may be appropriate.
GW-3	Groundwater Extraction/Disposal	Yes	1, 2, 3	Groundwater extraction and POTW disposal without treatment is expected to reduce the mass of TCE and to limit its migration in groundwater. Implementation of this alternative is dependent on POTW discharge requirements for this site.
GW-4	Groundwater Extraction/Ex-Situ Treatment/Disposal	Yes	1, 2	Groundwater extraction, ex-situ treatment, and reinjection or POTW disposal is expected to reduce the mass of TCE and to limit its migration in groundwater. This alternative is retained in the event treatment is necessary to meet POTW discharge limits.
GW-5	In-Situ Groundwater Treatment	Yes	1, 2, 3	In-situ treatment of groundwater is expected to reduce the mass of TCE and to limit its migration in groundwater. Total treatment time is expected to be less than that for groundwater extraction alternatives.

Key to reasons for retaining an alternative:

1. Implementable/Technically Feasible
2. Effective
3. Cost Effective

FS = Feasibility Study
RI = Remedial Investigation
TCE = Trichloroethylene
VOC = Volatile organic compound
POTW = Publicly owned treatment works

3.2.2 Alternative GW-2: Limited Action/Institutional Controls/Natural Attenuation

Description. The Limited Action alternative assumes semiannual groundwater monitoring for VOCs at monitoring wells MW-3, MW-4, and MW-5 for 5 years, with natural attenuation monitoring as necessary.

Monitoring would be discontinued after 2 years if the results of four consecutive sampling events indicate TCE concentrations satisfy the RAOs. In addition, property or water-use restrictions may be utilized to prevent the use of groundwater as drinking water. This alternative also assumes that an NFA ruling would be pursued for the Seattle ANGS.

Natural attenuation monitoring would be included as appropriate, based on the results of the Phase II RI. Monitored parameters would include, at a minimum, baseline measurements for biodegradation indicators (e.g., dissolved oxygen, redox, methane, carbon dioxide, nitrate, ferrous iron, and sulfate). The VOC intermediate- and end-products of TCE degradation would also be monitored, and their concentrations compared to expected levels based on available stoichiometric and kinetic data for TCE degradation. Monitoring would be conducted on a semiannual or annual basis for 1 to 2 years.

Evaluation. In order to obtain an NFA ruling, it may be necessary to monitor groundwater (with or without natural attenuation parameters) for a limited period of time and/or restrict future use of the shallow groundwater at the Seattle ANGS.

Groundwater monitoring is typically required to determine whether contaminant concentrations are increasing, stable, or decreasing with time. A stable or decreasing trend in contaminant concentrations provides assurance that the contaminants are not migrating in groundwater. Natural attenuation monitoring is typically conducted to determine the efficacy and rates of intrinsic remediation at a site, and can include collection of hydrogeologic, dispersion, adsorption, biodegradation and contaminant source data.

This alternative meets the criteria of effectiveness, implementability, and cost, and is therefore retained for further evaluation.

3.2.3 Alternative GW-3: Groundwater Extraction/Disposal

Description. Alternative GW-3 assumes the installation of two 6-inch diameter groundwater extraction wells to approximately 20 feet bgs in the vicinity of the former washrack; groundwater extraction for a minimum of

2 years with system monitoring; quarterly groundwater monitoring for 2 years, followed by semiannual monitoring for 2 years; and discharge of untreated groundwater to the local publicly owned treatment works (POTW).

The extraction system would consist of submersible pumps placed in the two extraction wells, manual throttling valves or other means of throttling flow, high amperage shut-offs with timed restarts for each pump, flow meters/totalizers, and sample ports. The discharge system would consist of underground piping to the nearest sanitary sewer inlet, and a flow meter/totalizer.

System monitoring would include cumulative and instantaneous flow measurements and the collection of extracted groundwater samples for VOC, pH, and solids analyses. Groundwater monitoring would include depth-to-water measurements and the collection of groundwater samples for VOC analysis at monitoring wells MW-3, MW-4, and MW-5.

Natural attenuation monitoring would be included as appropriate, based on the results of the Phase II RI. Monitored parameters would include, at a minimum, baseline measurements for biodegradation indicators (e.g., dissolved oxygen, redox, methane, carbon dioxide, nitrate, ferrous iron, and sulfate). The VOC intermediate- and end-products of TCE degradation would also be monitored, and their concentrations compared to expected levels based on available stoichiometric and kinetic data for TCE degradation. Monitoring would be conducted on a semiannual or annual basis during remediation activities and for 1 to 2 years following system shutdown, as appropriate.

The local POTW for the Seattle ANGS is operated by Metro, located in Seattle, Washington. Metro has a maximum discharge limit of 2.13 milligrams per liter (mg/L) total toxic organics (TTO) for sewer system discharges associated with metal finishing and electroplating sites. Although other types of sites are evaluated on a case-by-case basis, maximum VOC concentrations detected to date at the Seattle ANGS are considerably lower than Metro's TTO limit, and relatively low discharge rates are anticipated. As such, acceptance of this waste stream by Metro is anticipated.

Evaluation. This alternative meets the criteria of effectiveness, implementability, and cost, and is therefore retained for further evaluation.

3.2.4 Alternative GW-4: Groundwater Extraction/Ex-Situ Treatment/Disposal

Description. Alternative GW-4 assumes the installation of two 6-inch diameter groundwater extraction wells installed to approximately 20 feet bgs in the vicinity of the former washrack; groundwater extraction for a minimum of 2 years with system monitoring; quarterly groundwater monitoring for 2 years, followed by semiannual monitoring for 2 years; treatment of extracted groundwater with GAC; and discharge of treated groundwater to the local POTW or to an on-site infiltration trench located upgradient of the former washrack.

The extraction system would consist of submersible pumps placed in the two extraction wells, throttling capability, high amperage shut-offs with timed restarts for each pump, flow meters/totalizers, sample ports, and underground conveyance piping to the treatment system. The treatment system would consist of two GAC vessels in series, preceded by an optional settling/batch tank and cartridge filters for solids removal. The discharge system would consist of underground piping to the sanitary sewer inlet or infiltration trench, and a flow meter/totalizer.

System monitoring would include cumulative and instantaneous flow measurements and the collection of GAC inlet, midpoint, and outlet samples for VOC analysis. Groundwater monitoring would include depth-to-water measurements and the collection of groundwater samples for VOC analysis at monitoring wells MW-3, MW-4, and MW-5.

Natural attenuation monitoring would be included as appropriate, based on the results of the Phase II RI. Monitored parameters would include, at a minimum, baseline measurements for biodegradation indicators (e.g., dissolved oxygen, redox, methane, carbon dioxide, nitrate, ferrous iron, and sulfate). The VOC intermediate- and end-products of TCE degradation would also be monitored, and their concentrations compared to expected levels based on available stoichiometric and kinetic data for TCE degradation. Monitoring would be conducted on a semiannual or annual basis during remediation activities and for 1 to 2 years following system shutdown, as appropriate.

Evaluation. This alternative meets the criteria of effectiveness and implementability. Although this alternative is expected to be more costly than Alternative GW-3, it is uncertain whether Metro will grant permission to discharge untreated groundwater directly to the POTW. Accordingly, Alternative GW-4 is retained for further evaluation.

3.2.5 Alternative GW-5: In-Situ Groundwater Treatment

Description. Alternative GW-5 assumes the installation of twenty-four 2-inch diameter air sparge wells installed to approximately 20 feet bgs and eight soil vapor extraction (SVE) wells installed to approximately 5 to 10 feet bgs in the vicinity of the former washrack; the injection of air and/or methane for a minimum of 1 year with system monitoring; and quarterly groundwater monitoring for 2 years, followed by semiannual monitoring for 1 year.

The air/methane injection system would consist of a methane source (e.g., compressed gas cylinders), two air compressors or air sparge blowers, an underground piping/header system to distribute air flow to the sparge wells, and pressure regulators and valves for each well. The SVE system would consist of a blower, a header system to distribute flow among the SVE wells, and valves for each well. In addition, an air emissions treatment system may be required. At the low SVE flows and VOC concentrations anticipated, vapor-phase GAC would likely be the most effective treatment technology for air emissions.

System monitoring would include field measurements of air-sparge and SVE system flows and total organic vapor concentrations (SVE system only). In addition, air samples would be collected from the SVE discharge and, if applicable, upstream of the air emissions treatment system. The air samples would be analyzed for VOCs, oxygen, carbon dioxide, and methane. Groundwater monitoring would include depth-to-water measurements and field testing of dissolved oxygen, pH, temperature, specific conductance, and redox. Additionally, groundwater samples collected at monitoring wells MW-3, MW-4, and MW-5 would be analyzed for VOCs.

Natural attenuation monitoring would be included as appropriate, based on the results of the Phase II RI. Monitored parameters would include, at a minimum, baseline measurements for biodegradation indicators (e.g., dissolved oxygen, redox, methane, carbon dioxide, nitrate, ferrous iron, and sulfate). The VOC intermediate- and end-products of TCE degradation would also be monitored, and their concentrations compared to expected levels based on available stoichiometric and kinetic data for TCE degradation. Monitoring would be conducted on a semiannual basis during remediation activities and for 1 to 2 years following system shutdown, as appropriate.

Evaluation. This alternative meets the criteria of effectiveness, implementability, and cost, and is therefore retained for further evaluation.

SECTION 4.0

DETAILED ANALYSIS OF ALTERNATIVES

4.1 Introduction

The five remedial alternatives developed in Section 3.0 require a detailed analysis to select the most appropriate alternative for groundwater remediation at the Seattle ANGS. Due to the incomplete site characterization data for VOCs at the time this report was prepared, the alternatives could not be defined sufficiently to complete the detailed analysis. Instead, this section describes the assessment criteria that will serve as the basis for conducting the detailed analysis and selecting an appropriate alternative once the Phase II RI is completed.

4.2 Assessment Criteria

The seven assessment criteria for the detailed analysis of remedial alternatives are listed below, followed by a brief description of each:

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

4.2.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment refers to the degree to which existing risks are reduced; the time required to reduce risk at the facility and attain cleanup standards; on-site and off-site risks resulting from implementation of the alternative; the degree to which the cleanup action may perform to a higher level than required by cleanup standards provided in the regulations; and improvement of the overall environmental quality.

4.2.2 Compliance with ARARs

Compliance with ARARs refers to the ability of the alternative to satisfy ARARs during construction, completion, and post-completion phases of the alternative.

4.2.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to the degree of certainty that the alternative will be successful; long-term reliability; magnitude of residual risk; and effectiveness of controls required to manage treatment residues or remaining wastes.

4.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Reduction of toxicity, mobility, or volume through treatment refers to the degree to which an alternative is capable of permanent destruction of a hazardous substance; the ability to reduce or eliminate hazardous substance releases and sources of releases; the degree of irreversibility of the waste treatment process; and the characteristics and quantity of treatment residuals generated.

4.2.5 Short-Term Effectiveness

Short-term effectiveness refers to the protection of human health and the environment during construction and implementation of the alternative, and the degree of risk to human health and the environment prior to attainment of the cleanup standards.

4.2.6 Implementability

Implementability refers to the ability of the alternative to be implemented, including consideration of whether the alternative is technically possible; availability of necessary on-site and off-site facilities, services, and materials; administrative and regulatory requirements; scheduling, size, complexity, and monitoring requirements; access for construction, operations, and monitoring; and integration with existing facility operations and other current or potential remedial actions.

4.2.7 Cost

Cost refers to the cost of the cleanup action. A cleanup action is not considered practical if the incremental cost of the cleanup action is substantial and disproportionate to the incremental degree of protection it would achieve over a lower-preference cleanup action.

4.3 Individual Analysis of Alternatives

Due to the incomplete site characterization data for VOCs, the individual analysis of alternatives is not presented in this report. The individual analysis will be conducted after the Phase II RI is completed.

4.4 Comparative Analysis

Due to the incomplete site characterization data for VOCs, the comparative analysis of alternatives is not presented in this report. The comparative analysis will be conducted after the Phase II RI is completed.

SECTION 5.0

RECOMMENDATIONS

Based on the results of the Phase I RI, five potential remedial alternatives have been developed and evaluated for the remediation of TCE in groundwater at the Seattle ANGS. These five alternatives require a detailed analysis before the most appropriate remedial alternative can be selected. Additional investigative work at the Station is recommended to identify the VOC source and fully define the extent of VOCs in soil and groundwater. This additional site characterization information is necessary for further definition and detailed analysis of the remedial alternatives. The scope of additional investigative work planned for the site is discussed in detail in the Phase II RI/FS Work Plan (ERM, 1998b).

SECTION 6.0

REFERENCES

Environmental Resources Management (ERM), 1996, *Installation Restoration Program (IRP) Final Remedial Investigation/Feasibility Study Work Plan, 143rd Combat Communications Squadron, Seattle Air National Guard Station,* July 1996.

ERM, 1998a, *Installation Restoration Program (IRP) Final Phase I Remedial Investigation Report, 143rd Combat Communications Squadron, Seattle Air National Guard Station,* May 1998.

ERM, 1998b, *Installation Restoration Program (IRP) Final Phase II RI/FS Work Plan, 143rd Combat Communications Squadron, Seattle Air National Guard Station,* July 1998.

U.S. Environmental Protection Agency (USEPA), 1988, *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA,* Office of Emergency and Remedial Response, October 1988.

USEPA, 1993, *Presumptive Remedies: Policy and Procedures,* USEPA 540-F-93-047, September 1993.

USEPA, 1996, *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites - Final Guidance,* USEPA 540-R-96-023, October 1996.

Washington State Department of Ecology (WDOE), 1996, *The Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC,* Publication No. 94-06, Amended January 1996.

APPENDIX A

GEOLOGIC CROSS SECTIONS

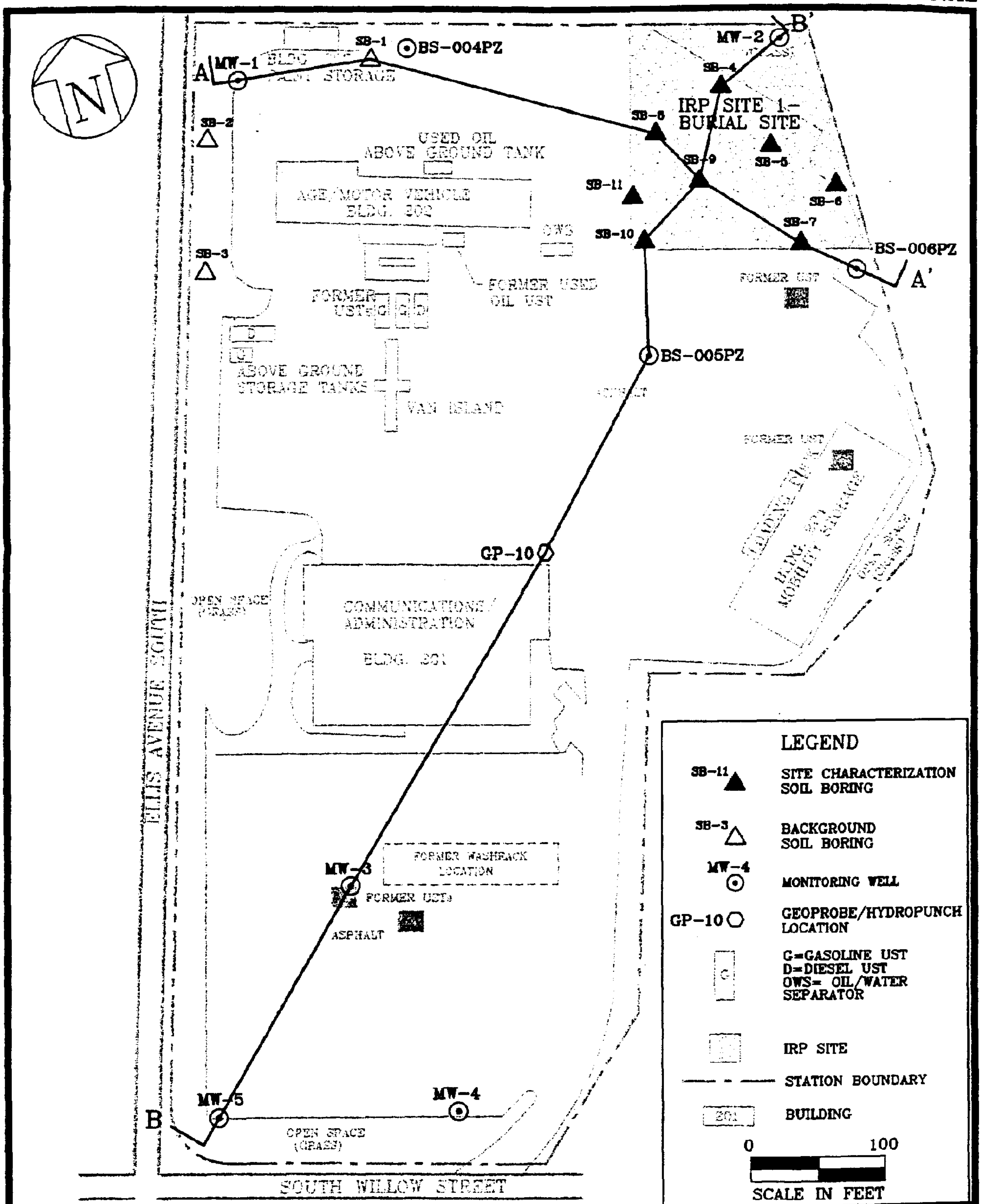

FIGURE A-1

GEOLOGIC CROSS-SECTION
LOCATION MAP
143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

80325-01.DWG

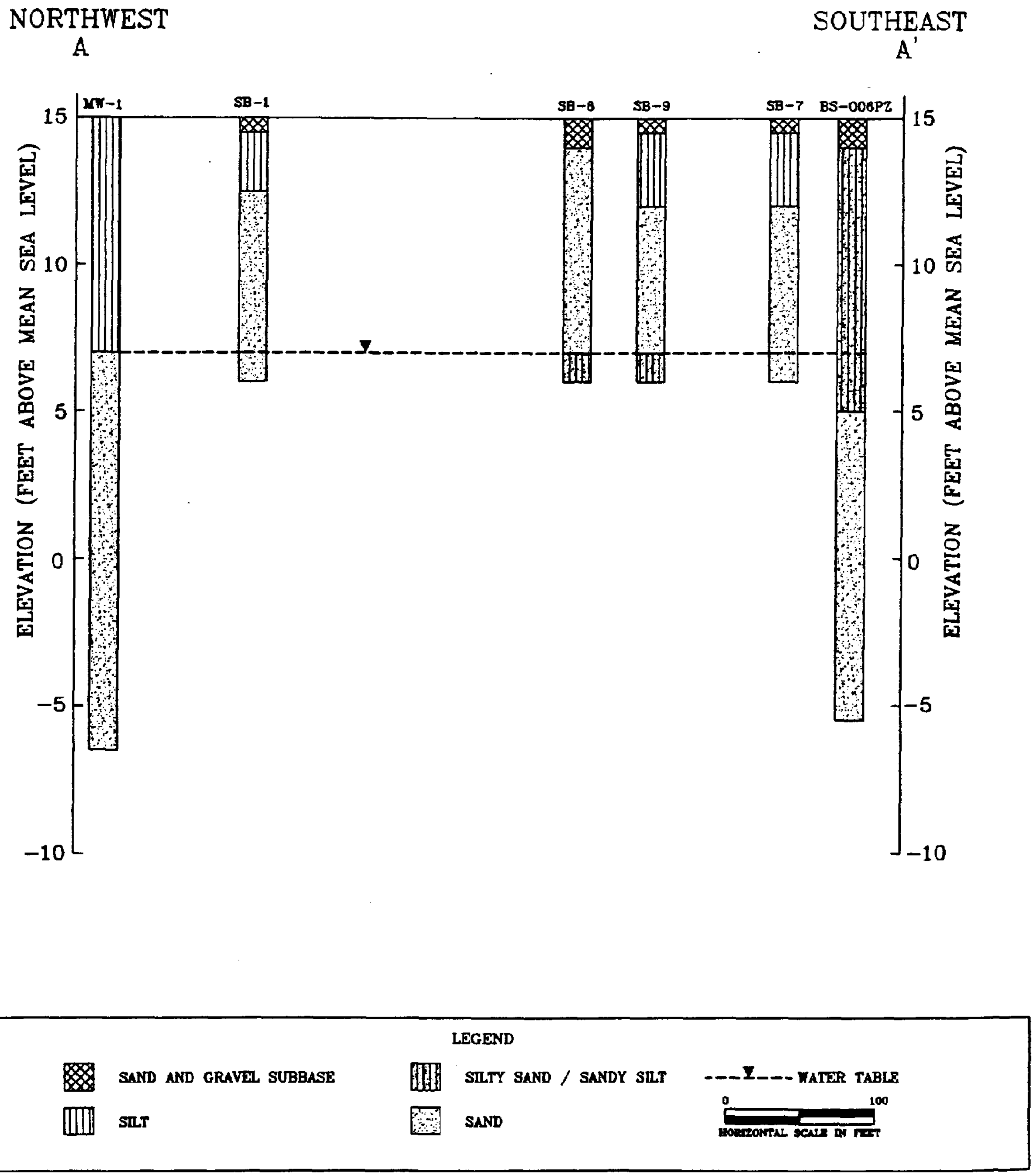

FIGURE A-2

60325-02.DWG

GEOLOGIC CROSS-SECTION A-A'

143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

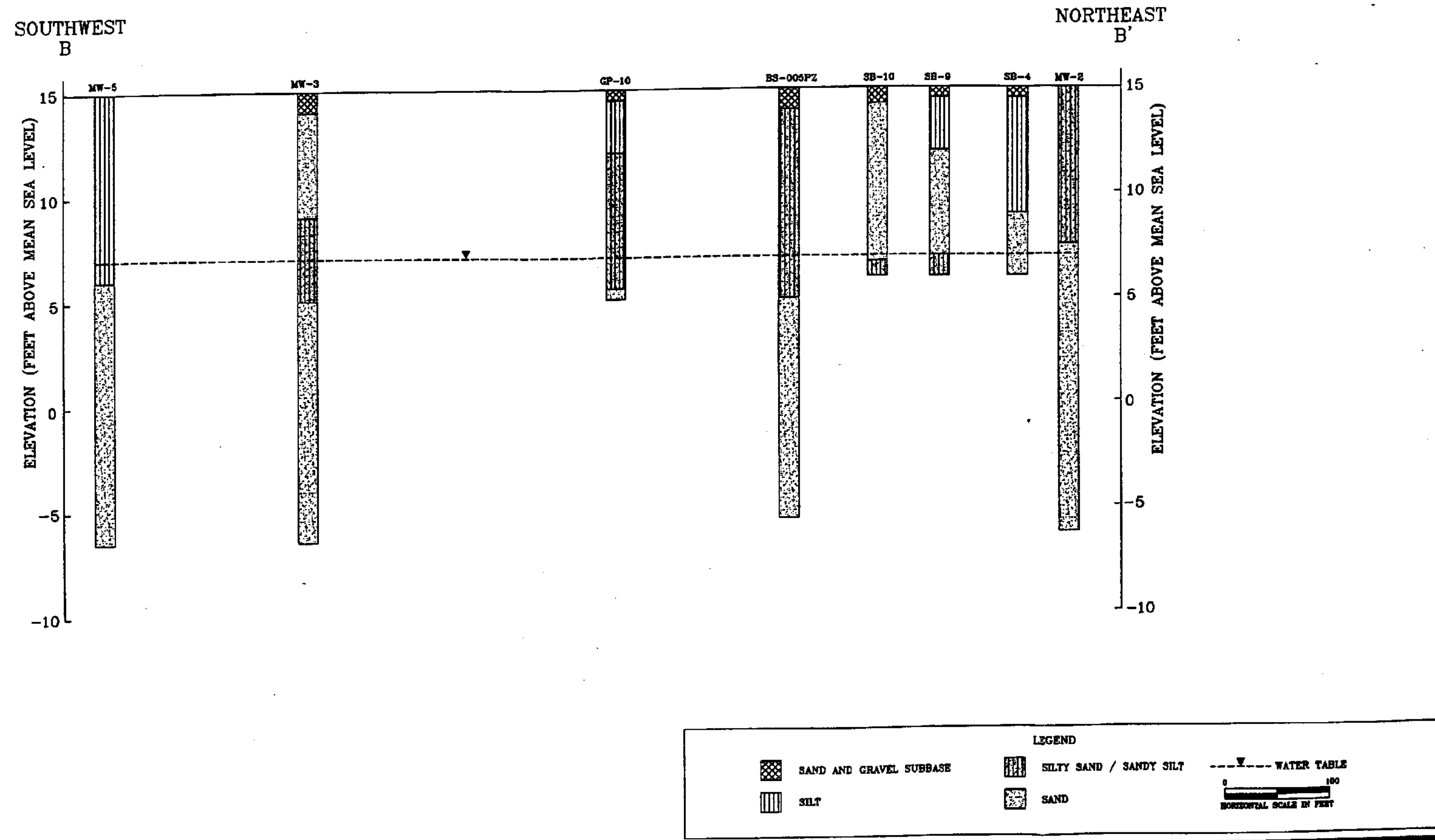

FIGURE A-3

60325-03.DWG

GEOLOGIC CROSS-SECTION B-B'

143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

APPENDIX B

HYDROGEOLOGIC DATA

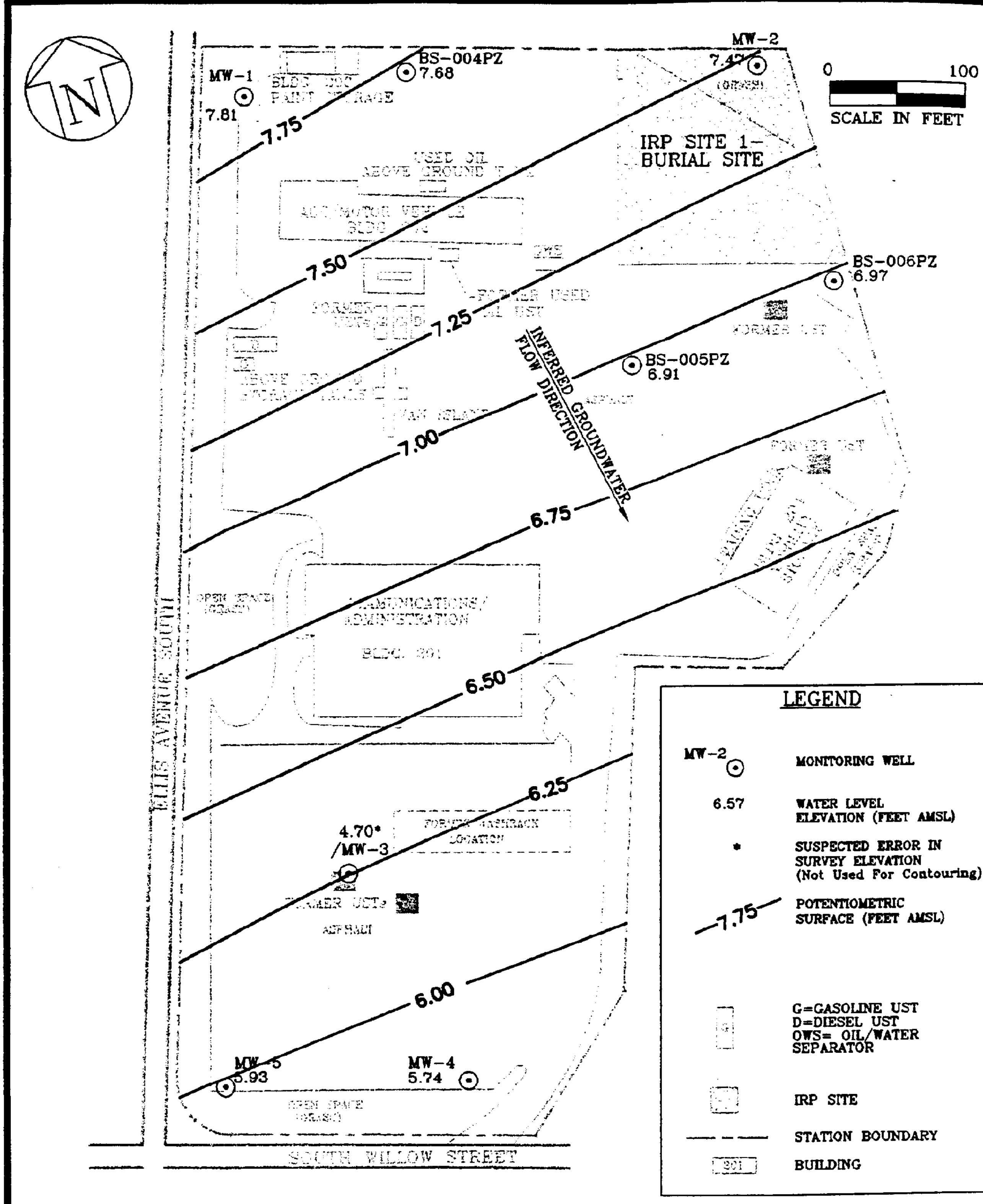

FIGURE B-1

POTENTIOMETRIC SURFACE
JANUARY 14-15, 1997

143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

60325-07 DWG

KCSlip4 40852

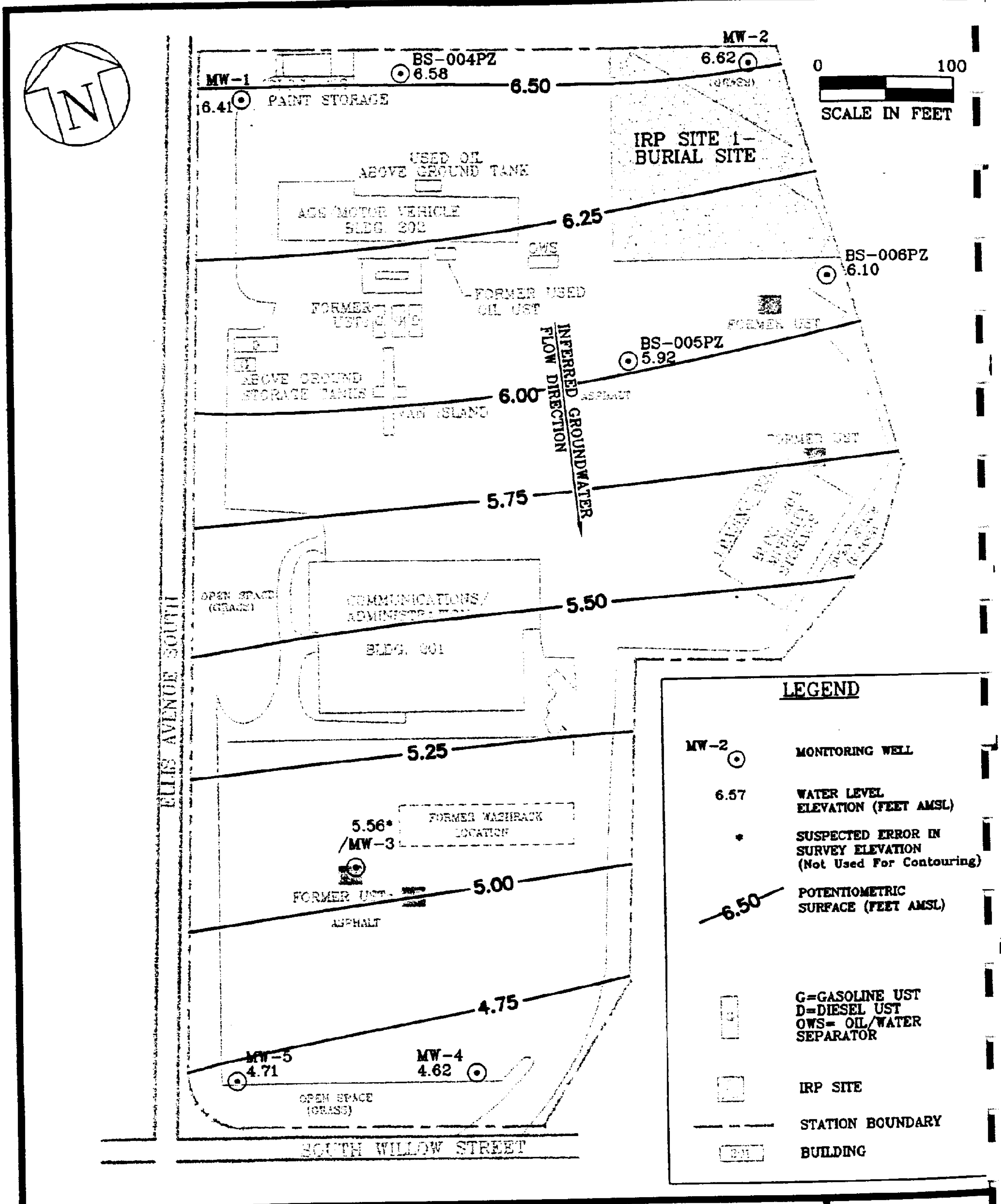

FIGURE B-2

POTENTIOMETRIC SURFACE
JULY 10-11, 1997

143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

60325-09 DWG

KCSlip4 40853

SEA407383

TABLE B-1

Monitoring Well Installation Summary
143rd CCSQ, Seattle ANGS, Seattle, Washington

Location	IRP Investigation	Date Completed	Measuring Point Elevation (ft-amsl)	Total Depth (ft-bgs)	Casing Diameter/ Material	Wellhead Completion	Screen Slot Size (inches)	Annular Seal	Screened Interval (ft-bgs)	Top of Sand Filter Pack (ft-bgs)
BS-004PZ (Background)	PA/SI	7/14/94	14.66	20.5	2-inch PVC	Flush	0.010	5-feet BC	9.0 - 19.0	7
MW-1 (Background)	RI	10/16/96	14.92	205	2-inch PVC	Flush	0.010	2-feet BC	10.0-20.0	7.5
BS-005PZ	PA/SI	7/14/94	14.39	20.5	2-inch PVC	Flush	0.010	5-feet BC	9.0 - 19.0	7
BS-006PZ	PA/SI	7/14/94	14.59	20.5	2-inch PVC	Flush	0.010	5-feet BC	9.0 - 19.0	7
MW-2	RI	10/16/96	14.60	20.5	2-inch PVC	Flush	0.010	2-feet BC	10.0-20.0	7.5
MW-3	RI	10/17/96	12.50*	20.5	2-inch PVC	Flush	0.010	2-feet BC	10.0-20.0	7.5
MW-4	RI	10/17/96	12.05	20.5	2-inch PVC	Flush	0.010	2-feet BC	10.0-20.0	7.5
MW-5	RI	10/17/96	13.94	20.5	2-inch PVC	Flush	0.010	2-feet BC	10.0-20.0	7.5

ft-amsl = Feet above mean sea level
ft-bgs = Feet below ground surface
RI = Remedial Investigation
PA/SI = Preliminary Assessment/Site Inspection
BC = Bentonite Chips
* = Suspected error in survey data

TABLE B-2

Monitoring Well Water Level Summary
143rd CCSQ, Seattle ANGS, Seattle, Washington

Location	Measuring Point Elevation (ft-amsl)	Date	Depth to Water (ft-bmp)	Water Level Elevation (ft-amsl)
BS-004PZ (Background)	14.66	9/17/96	8.88	5.78
		10/22/96	8.93	5.73
		12/17/96	8.08	6.58
		1/14/97	6.98	7.68
		4/11/97	7.23	7.43
		7/10/97	8.08	6.58
BS-005PZ	14.39	9/17/96	9.16	5.23
		10/22/96	9.42	4.97
		12/17/96	8.51	5.88
		1/15/97	7.48	6.91
		4/10/97	7.65	6.74
		7/11/97	8.47	5.92
BS-006PZ	14.59	9/17/96	9.12	5.47
		10/22/96	9.47	5.12
		12/17/96	8.54	6.05
		1/14/97	7.62	6.97
		4/11/97	7.77	6.82
		7/11/97	8.49	6.10
MW-1 (Background)	14.92	10/22/96	9.18	5.74
		12/17/96	8.20	6.72
		1/14/97	7.11	7.81
		4/10/97	7.58	7.34
		7/11/97	8.51	6.41
MW-2	14.60	10/22/96	8.89	5.71
		12/17/96	8.03	6.57
		1/15/97	7.13	7.47
		4/10/97	7.25	7.35
		7/11/97	7.98	6.62
MW-3	12.50*	10/22/96	7.77	4.73
		12/17/96	6.78	5.72
		1/15/97	7.80	4.70
		4/11/97	6.06	6.44
		7/11/97	6.94	5.56
MW-4	12.05	10/22/96	8.20	3.85
		12/17/96	7.21	4.84
		1/14/97	6.31	5.74
		4/11/97	6.65	5.40
		7/11/97	7.43	4.62
MW-5	13.94	10/22/96	10.06	3.88
		12/17/96	9.06	4.88
		1/14/97	8.01	5.93
		4/11/97	8.36	5.58
		7/10/97	9.23	4.71

ft-amsl = Feet above mean sea level
ft-bmp = Feet below measuring point
* = Suspected error in survey data

APPENDIX C

PHASE I REMEDIAL INVESTIGATION SAMPLING LOCATIONS AND ANALYSES

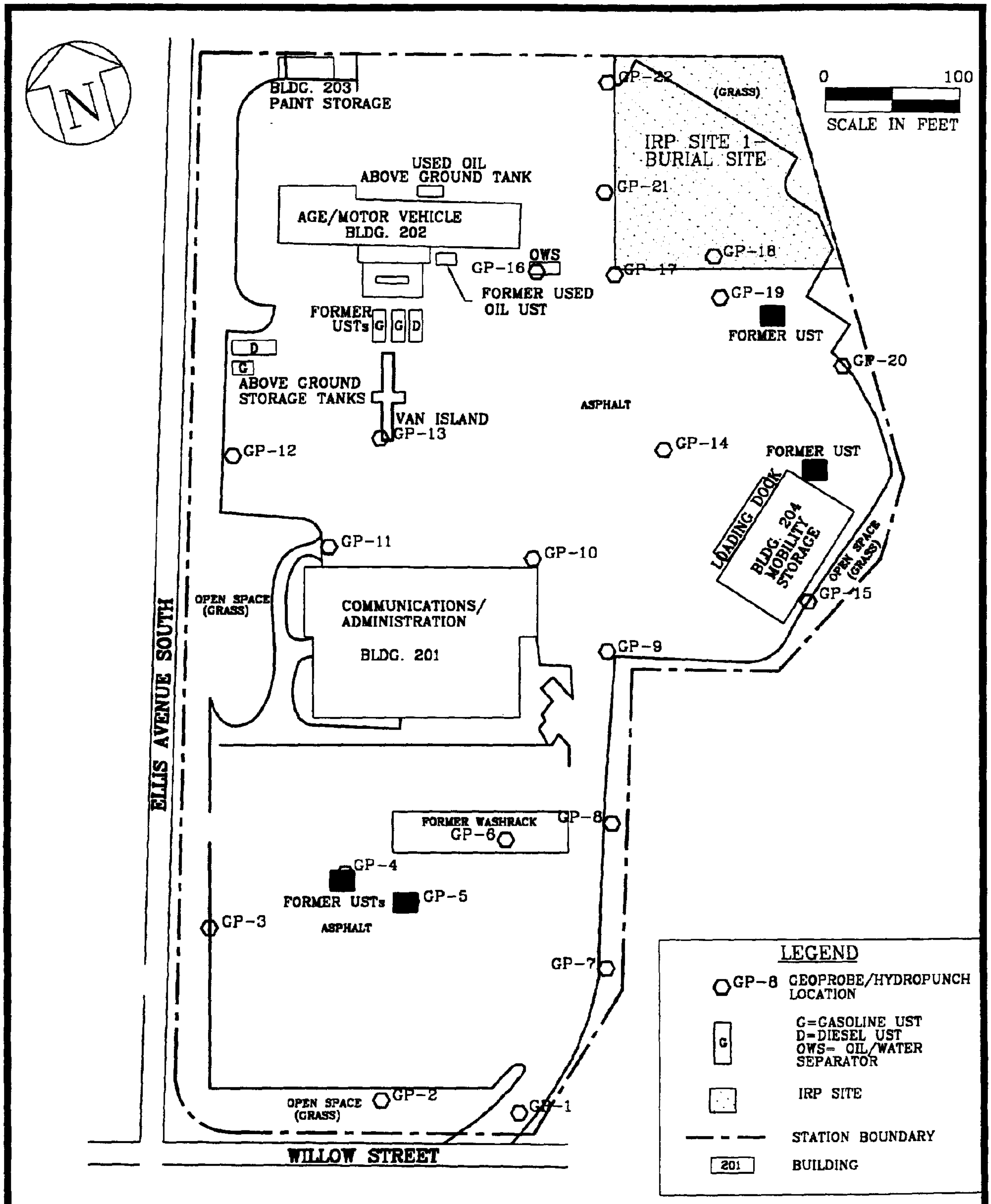

FIGURE C-1

PHASE I RI GEOPROBE/HYDROPUNCH
GROUNDWATER SAMPLING LOCATIONS
143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

S:\CAD\DWGS\6032\41\60324102

C-1

KCSlip4 40857

SEA407387

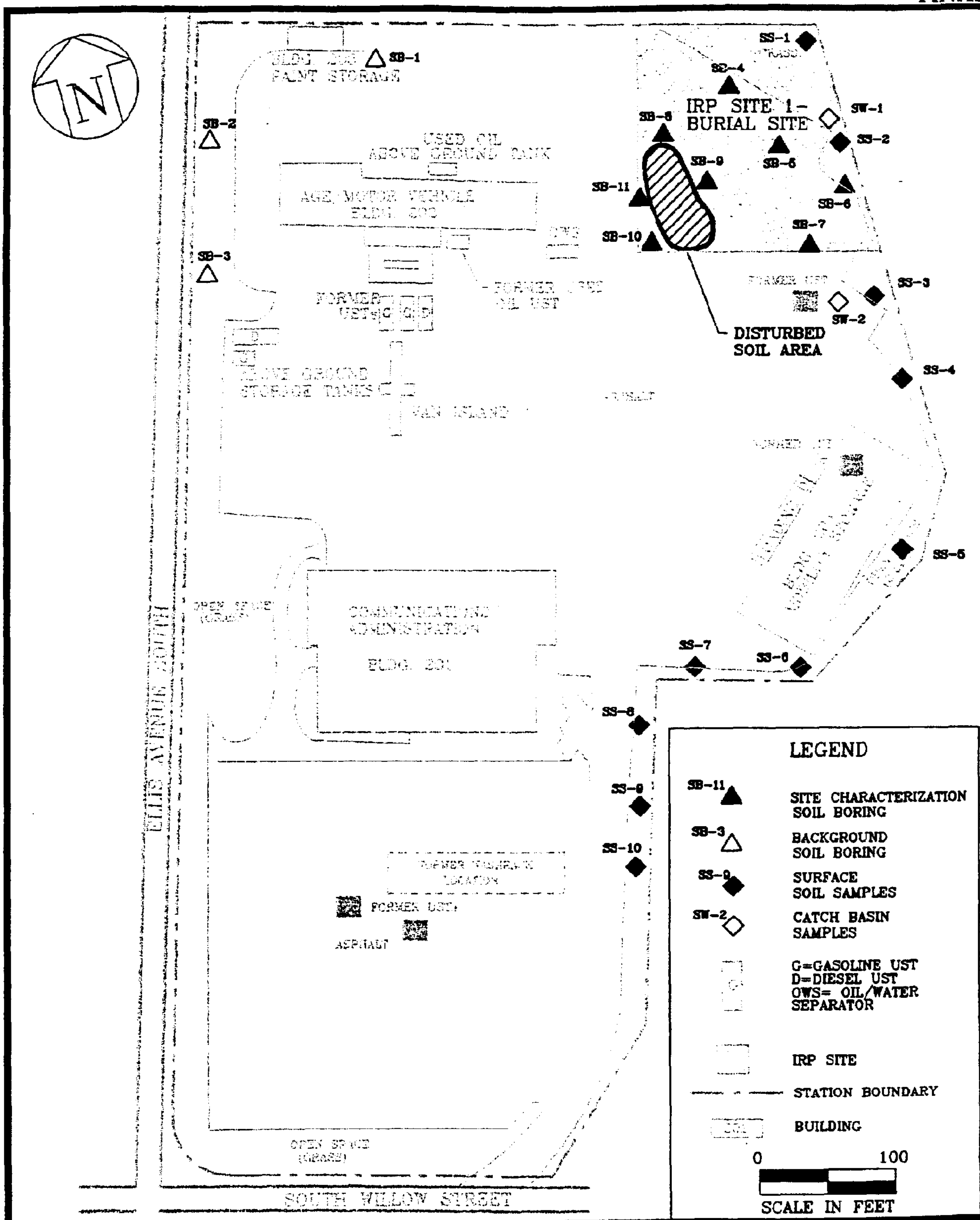

FIGURE C-2

PHASE I RI SOIL SAMPLING LOCATIONS

143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

90324-02.DWG

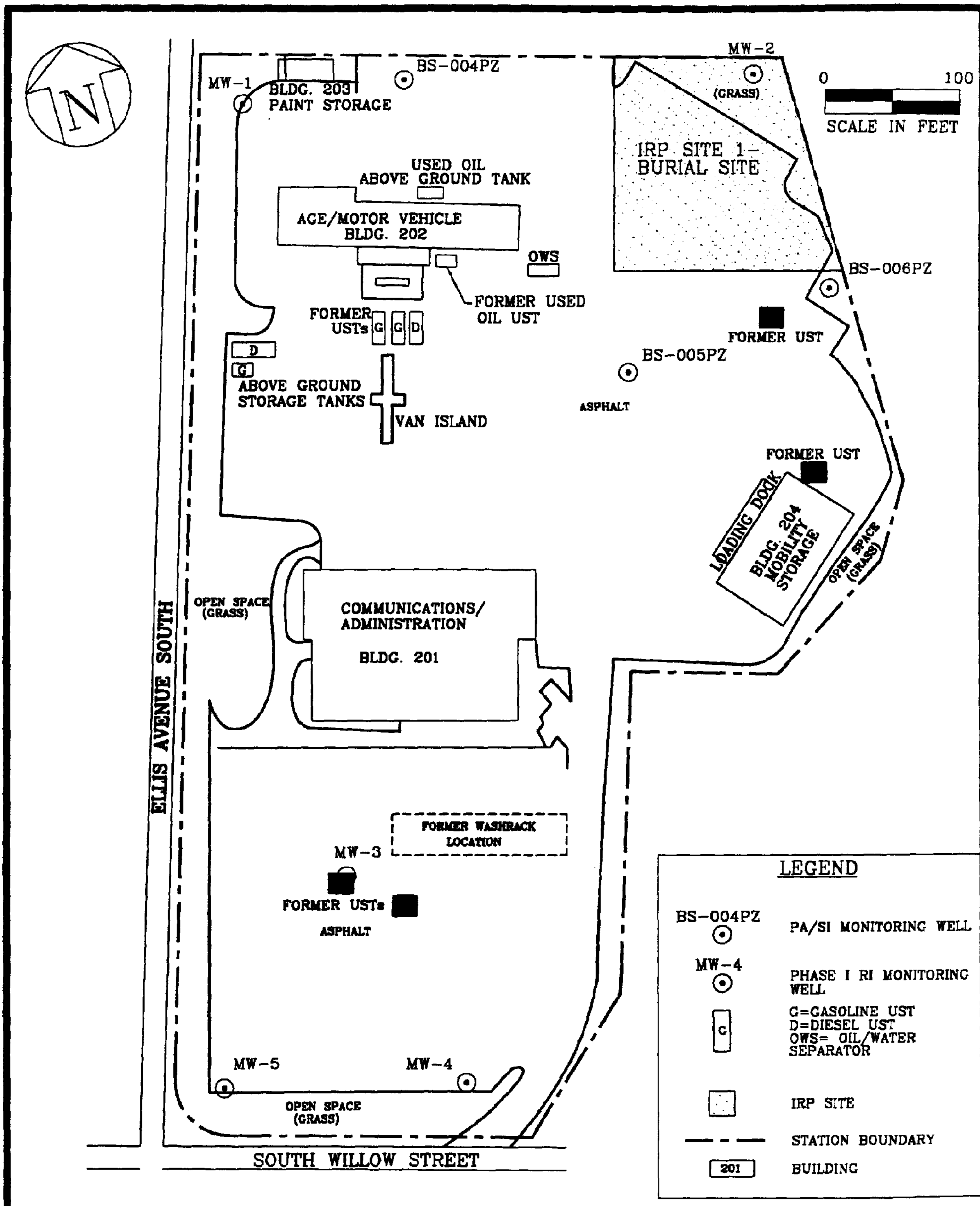

FIGURE C-3

S:\CAD\DWGS\6032\41\60324104

MONITORING WELL LOCATIONS

143rd CCSQ, Seattle ANGS
Seattle, Washington

ERM

KCSlip4 40859

SEA407389

TABLE C-1

Phase I Remedial Investigation Sampling Program
143rd CCSQ, Seattle ANGS, Seattle, Washington

Site	Matrix	Sampling Method	Field Parameters	Lab Parameters	USEPA Method	Primary Samples	QA/QC Samples					Matrix Total*
							Trip Blank	Rinsate Blank	Field Blank	Field Duplicate	MS/MSD	
Background	Subsurface Soil 3 Locations	Soil Borings	Soil headspace screening using PID/field TPH	PP Metals	3050/6010/6020/ 7470	9		1		1		10
			Soil Classification	SVOCs	3550/8270	9		1		1		10
				TPH	WTPH-HCID (1)	9		1		1		10
				Radionuclides	SM-7110A/B, 903.1, 904.0	9		1		1		10
	Groundwater 1 RI MW 1 PA/SI MW	Monitoring Wells (per round)	Temperature	PP Metals	6010/6020/7470	2						2
			pH	VOCs	5030/8260	2	1					2
			Specific conductance	SVOCs	3550/8270	2						2
			Turbidity	TPH	WTPH-HCID (1)	2						2
				Radionuclides	SM-7110A/B, 903.1, 904.0	2						2
IRP Site No.1	Subsurface Soil 8 Locations	Soil Borings	Soil headspace screening using PID/field TPH	PP Metals	3050/6010/6020/ 7470	16		1	1	1	2	19
			Soil Classification	TPH	WTPH-HCID (1)	16		1	1	1	2	19
				SVOCs	3550/8270	16		1	1	1	2	19
				Radionuclides	SM-7110A/B, 903.1, 904.0	16		1	1	1	2	19
	Storm Sewer Catch Basin Contents 2 Locations	Grab Samples	Soil headspace screening using PID/field TPH	PP Metals	3050/6010/6020/ 7470	2						2
				TPH	WTPH-HCID (1)	2						2
				SVOCs	3550/8270	2						2
				VOCs	5030/8260	2						2
				Radionuclides	SM-7110A/B, 903.1, 904.0	2						2

TABLE C-1

Phase I Remedial Investigation Sampling Program
143rd CCSQ, Seattle ANGS, Seattle, Washington

Site	Matrix	Sampling Method	Field Parameters	Lab Parameters	USEPA Method	Primary Samples	QA/QC Samples					Matrix Total*
							Trip Blank	Rinsate Blank	Field Blank	Field Duplicate	MS/MSD	
IRP Site No. 1 (cont.)	Surface Soil 10 Locations	Surface Sampling	Soil headspace screening using PID/field TPH	TPH	WTPH-HCID (1) WTPH - G/D/HO (2)	10			1	1	1	12
			Soil Classification	Radionuclides	SM-7110A/B, 903.1, 904.0	10			1	1	1	12
	Groundwater	HydroPunch (field lab)	Temperature pH	Selected VOCs	8010/8020	22				2	1	25
			Specific conductance	TPH	WTPH-HCID (1)	22				2	1	25
	4 RI MWs 2 PA/SI MWs	Monitoring Wells (per round)	Temperature	PP Metals	6010/6020/7470	6		1	1	1	1	8
			pH	VOCs	5030/8260	6	1	1	1	1	1	8
			Specific conductance	SVOCs	3550/8270	6		1	1	1	1	8
				TPH	WTPH-HCID (1)	6		1	1	1	1	8
			Turbidity	Radionuclides	SM-7110A/B, 903.1, 904.0	6		1	1	1	1	8

VOCs = Volatile organic compounds
SVOCs = Semivolatile organic compounds
PP Metals = Priority Pollutant metals
TPH = Total petroleum hydrocarbons
QA/QC = Quality assurance/quality control
MS/MSD = Matrix spike/matrix spike duplicate
USEPA = United States Environmental Protection Agency
PID = Photoionization detector
RI = Remedial Investigation
PA/SI = Preliminary Assessment/Site Inspection
MW = Monitoring Well
* = Blank samples not included in matrix total
(1) = State of Washington TPH analysis - hydrocarbon screening/identification method
(2) = State of Washington TPH analysis - gasoline/diesel/heavy oil quantification method

TABLE C-2

Trichloroethylene Detected in
Geoprobe/HydroPunch Groundwater Samples
143rd CCSQ, Seattle ANGS, Seattle, Washington

Sample Location	Sample Date	TCE Concentration (ug/L)*
GP-01	10/8/96	ND
GP-02	10/8/96	3.7
GP-03	10/8/96	ND
GP-04	10/8/96	**17**
GP-05	10/8/96	4.1
GP-06	10/8/96	ND
GP-07	10/8/96	ND
GP-08	10/8/96	ND
GP-09	10/8/96	ND
GP-10	10/9/96	ND
GP-11	10/9/96	ND
GP-12	10/9/96	ND
GP-13	10/9/96	ND
GP-14	10/9/96	ND
GP-15	10/9/96	ND
GP-16	10/9/96	ND
GP-17	10/9/96	ND
GP-18	10/9/96	ND
GP-19	10/9/96	ND
GP-20	10/9/96	ND
GP-21	10/9/96	ND
GP-22	10/9/96	ND

*Analyzed by USEPA Method 8010

TCE = Trichloroethylene
ug/L = Micrograms per liter
ND = Not detected above method reporting limit
Note: Shaded/bold values exceed the MTCA Method A Cleanup Level (5 ug/L).

TABLE C-3

Trichloroethylene Detected in Monitoring-Well Groundwater Samples
143rd CCSQ, Seattle ANGS, Seattle, Washington

Date	TCE Concentration in Background Wells (ug/L)*		TCE Concentration (ug/L)*					
	BS-004PZ	MW-01	BS-005PZ	BS-006PZ	MW-02	MW-03	MW-04	MW-05
9/17/96	ND (ND)	NA	ND	ND	NA	NA	NA	NA
10/15-18/1996	NA	ND	NA	NA	ND	ND (ND)	3.9	ND
12/17/96	NA	ND	NA	NA	ND	ND (ND)	2.7	ND
1/14-15/1997	ND	ND	ND	ND	ND (ND)	ND	3.4	ND
4/10-11/1997	ND	ND	ND	ND	ND	ND	3.2	ND (ND)
7/11/97	ND	ND	ND	ND	ND	ND	2.8	2.1 (ND)

*Analyzed by USEPA Method 8260

TCE = Trichloroethylene
ug/L = Micrograms per liter
NA = Not analyzed
ND = Not detected above method reporting limit
( ) = Duplicate sample results

APPENDIX D

IDENTIFICATION OF CONTAMINANTS OF CONCERN

TABLE D-1

Identification of Contaminants of Concern in Soil
143 rd CCSQ, Seattle ANGS, Seattle, Washington

Constituent Detected	Project Screening Goal	Units	Confirmed COC? (Y/N)	Reason	Maximum Site-Specific Background Concentration Detected	Maximum Screening Concentration Detected	Maximum Site-Characterization Concentration Detected
Bis(2-ethylhexyl)phthalate	71.4	mg/kg	N	No occurrences above the PSG; suspected lab contaminant.	Not detected.	No field screening for SVOCs.	1 detect: SB-09 @ 9ft bgs on 10/16/96: 3.9 mg/kg.
TPH-Gasoline	100	mg/kg	N	No occurrences above the PSG.	Not detected.	Immunoassay field technique - max TPH > 100 ppm.	2 detects: maximum @ SS-10 @ 0.5 ft bgs on 10/17/96: 35 mg/kg.
TPH-Diesel	200	mg/kg	N	No occurrences above the PSG.	Not detected.	Immunoassay field technique - max TPH > 100 ppm.	3 detects: maximum @ SS-07 @ 0.5 ft bgs on 10/17/96: 70 mg/kg.
TPH-Heavy oil	200	mg/kg	N	No occurrences above the PSG.	Not detected.	Immunoassay field technique - max TPH > 100 ppm.	2 detects: maximum @ SS-09 @ 0.5 ft bgs on 10/17/96: 110 mg/kg.
Trichloroethylene	0.5	mg/kg	N	No occurrences above the PSG; presence likely due to VOC impacts to groundwater.	Not detected.	No compound-specific field screening for VOCs.	1 detect: MW-3 @ 9ft bgs on 10/16/96: 0.17 mg/kg.
Gross Alpha Particle Activity	9.96	pCi/g	N	Per letter dated 05/09/97 from the State of Washington Department of Health - Division of Radiation Protection: Radiation in soil is present at background levels.	9 detects - maximum @ SB-3 @ 3 ft bgs on 10/15/96: 12.8 pCi/g.	No field screening for radionuclides.	25 detects: maximum @ SB-05 @ 3 ft bgs on 10/15/96: 16.2 pCi/g.
Gross Beta Particle Activity	16.1	pCi/g	N	Per letter dated 05/09/97 from the State of Washington Department of Health - Division of Radiation Protection: Radiation in soil is present at background levels.	9 detects - maximum @ SB-1 @ 9 ft bgs on 10/15/96: 16.6 pCi/g.	No field screening for radionuclides.	25 detects: maximum @ SB-09 @ 9 ft bgs on 10/16/96: 22.9 pCi/g.
Radium-226	0.77	pCi/g	N	Per letter dated 05/09/97 from the State of Washington Department of Health - Division of Radiation Protection: Radiation in soil is present at background levels.	9 detects - maximum @ SB-2 @ 7 ft bgs on 10/15/96: 0.88 pCi/g.	No field screening for radionuclides.	25 detects: maximum @ SB-07 @ 3 ft bgs on 10/15/96: 1.37 pCi/g.
Radium-228	0.93	pCi/g	N	Per letter dated 05/09/97 from the State of Washington Department of Health - Division of Radiation Protection: Radiation in soil is present at background levels.	9 detects - maximum @ SB-1 @ 7 ft bgs on 10/15/96: 1.34 pCi/g.	No field screening for radionuclides.	25 detects: maximum @ SB-10 & SB-11 @ 9 ft bgs on 10/15/96: 1.29 pCi/g.
Arsenic	20	mg/kg	N	No occurrences above the PSG.	9 detects - maximum @ SB-3 @ 3 ft bgs on 10/15/96: 8.7 mg/kg.	No field screening for metals.	14 detects: maximum @ SB-09 (dup) @ 3ft bgs on 10/16/96: 20 mg/kg.
Cadmium	2	mg/kg	N	No occurrences above the PSG.	Not detected.	No field screening for metals.	1 detect: SB-04 @ 3ft bgs on 10/15/96: 0.8 mg/kg.

TABLE D-1

Identification of Contaminants of Concern in Soil
143 rd CCSQ, Seattle ANGS, Seattle, Washington

Constituent Detected	Project Screening Goal	Units	Confirmed COC? (Y/N)	Reason	Maximum Site-Specific Background Concentration Detected	Maximum Screening Concentration Detected	Maximum Site-Characterization Concentration Detected
Chromium	100	mg/kg	N	No occurrences above the PSG.	9 detects - maximum @ SB-3 @ 3 ft bgs on 10/15/96: 17 mg/kg.	No field screening for metals.	16 detects: maximum @ SB-05 @ 9ft bgs on 10/15/96: 19 mg/kg.
Copper	2,960	mg/kg	N	No occurrences above the PSG.	9 detects - maximum @ SB-2 @ 5 ft bgs on 10/15/96: 20 mg/kg.	No field screening for metals.	16 detects: maximum @ SB-04 @ 3ft bgs on 10/15/96: 35 mg/kg.
Lead	250	mg/kg	N	No occurrences above the PSG.	6 detects - maximum @ SB-2 @ 5 ft bgs on 10/15/96: 33 mg/kg.	No field screening for metals.	16 detects: maximum @ SB-09 (dup) @ 3ft bgs on 10/16/96: 250 mg/kg.
Nickel	1,600	mg/kg	N	No occurrences above the PSG.	9 detects - maximum @ SB-3 @ 3 ft bgs on 10/15/96: 14 mg/kg.	No field screening for metals.	16 detects: maximum @ SB-05 @ 9ft bgs on 10/15/96: 24 mg/kg.
Selenium	400	mg/kg	N	No occurrences above the PSG.	5 detects - maximum @ SB-3 @ 3 ft bgs on 10/15/96: 2.8 mg/kg.	No field screening for metals.	5 detects: maximum @ SB-04 & SB-06 @ 3ft bgs on 10/15/96: 1.5 mg/kg.
Zinc	24,000	mg/kg	N	No occurrences above the PSG.	9 detects - maximum @ SB-2 @ 5 ft bgs on 10/15/96: 45 mg/kg.	No field screening for metals.	16 detects: maximum @ SB-09 (dup) @ 3ft bgs on 10/16/96: 210 mg/kg.

Note: Number of detects includes those associated with primary samples only; duplicate samples are not included in this number.
Note: For the radionuclides, the number of detects does not include negative values.

COC = Contaminant of concern
ft bgs = Feet below ground surface
mg/kg = Milligrams per kilogram
pCi/g = PicoCuries per gram
PSG = Project screening goal
SVOC = Semivolatile organic compound
TPH = Total petroleum hydrocarbons
VOC = Volatile organic compound

TABLE D-2

Identification of Contaminants of Concern in Groundwater
143rd CCSQ, Seattle ANGS, Seattle, Washington

Constituent Detected	Project Screening Goal	Units	Confirmed COC? (Y/N)	Reason	Maximum Site-Specific Background Concentration Detected	Maximum Screening Concentration Detected	Maximum Site-Characterization Concentration Detected
Acetone	800	µg/L	N	No occurrences above the PSG.	Not detected.	Not detected.	2 detects: maximum @ MW-3 (dup) on 10/18/96: 20 µg/L.
Benzene	5	µg/L	N	Benzene complies with MTCA Method A and Federal MCL criteria based on a statistical screening evaluation of the data.	Not detected.	HydroPunch sample - collected 10/08/96: 2 detects: maximum @ GP-3: 7.6 µg/L.	Not detected.
1,1-Dichloroethane	800	µg/L	N	No occurrences above the PSG.	1 detect: @ BS-004PZ on 09/19/96: 0.3 µg/L.	Not detected.	Not detected.
1,2-Dichloroethane	5	µg/L	N	No occurrences above the PSG.	Not detected.	HydroPunch sample - collected 10/08/96: 1 detect @ GP-3: 2.4 µg/L.	Not detected.
cis-1,2-Dichloroethene	70	µg/L	N	No occurrences above the PSG.	Not detected.	HydroPunch sample - collected 10/08/96: 4 detects - maximum @ GP-15: 5 µg/L.	5 detects: maximum @ MW-05 on 10/18/96: 5.6 µg/L.
Ethylbenzene	30	µg/L	N	No occurrences above the PSG.	Not detected.	HydroPunch sample - collected 10/08/96: 1 detect @ GP-5: 9.9 µg/L.	Not detected.
Tetrachloroethene	5	µg/L	N	No occurrences above the PSG.	Not detected.	Not detected.	1 detect: @ BS-005PZ on 07/11/97: 4.7 µg/L.
Toluene	40	µg/L	N	No occurrences above the PSG.	1 detect: @ MW-1 on 01/14/97: 1.1 µg/L.	HydroPunch sample - collected 10/08/96: 1 detect @ GP-5: 1.6 µg/L.	Not detected.
1,1,1-Trichloroethane	200	µg/L	N	No occurrences above the PSG.	5 detects: maximum @ BS-004PZ (dup) on 09/17/96: 3.8 µg/L.	HydroPunch sample - collected 10/08/96: 1 detect @ GP-22: 2 µg/L.	Not detected.
Trichloroethylene	5	µg/L	Y	One HydroPunch sample exceeds 2x the MTCA Method A Cleanup Level; does not meet statistical criteria for compliance.	Not detected.	HydroPunch sample - collected 10/08/96: 3 detects - maximum @ GP-4: 17 µg/L.	6 detects: maximum @ MW-4 on 10/18/96: 3.9 µg/L.
1,3,5-Trimethylbenzene	0.507	µg/L	N	No occurrences above the PSG.	Not detected.	Not detected.	2 detects: @ BS-005PZ and BS-006PZ on 09/17/96: 0.3 µg/L.
Xylenes	20	µg/L	N	No occurrences above the PSG.	Not detected.	HydroPunch sample - collected 10/08/96: 1 detect @ GP-22: 7 µg/L.	Not detected.
Gross Alpha Particle Activity	15	pCi/L	N	No occurrences above the PSG; reflects area background.	6 detects - maximum @ MW-1 on 12/17/96: 3.9 pCi/L.	No field screening for radionuclides.	19 detects: maximum @ MW-04 on 10/18/96: 10.8 pCi/L.
Gross Beta Particle Activity	11.3	pCi/L	N	15 detects > PSG; reflects area background.	9 detects - maximum @ BS-004PZ on 12/17/96: 13.2 pCi/L. (3 detects > PSG).	No field screening for radionuclides.	28 detects: maximum @ BS-005PZ on 09/17/96: 20 pCi/L. (15 detects > PSG)

TABLE D-2

Identification of Contaminants of Concern in Groundwater
143 rd CCSQ, Seattle ANGS, Seattle, Washington

Constituent Detected	Project Screening Goal	Units	Confirmed COC? (Y/N)	Reason	Maximum Site-Specific Background Concentration Detected	Maximum Screening Concentration Detected	Maximum Site-Characterization Concentration Detected
Radium-226	3	pCi/L	N	No occurrences above the PSG; reflects area background	9 detects - maximum @ MW-1 on 01/14/97: 0.35 pCi/L.	No field screening for radionuclides.	28 detects: maximum @ MW-03 on 01/05/97 and MW-05 on 01/14/97: 0.21 pCi/L.
Radium-226 and 228	5	pCi/L	N	No occurrences above the PSG; reflects area background	9 detects - maximum @ MW-1 on 01/14/97: 0.66 pCi/L.	No field screening for radionuclides.	28 detects: maximum @ MW-03 (dup) on 10/18/96: 2.03 pCi/L.
Radium-228	2	pCi/L	N	No occurrences above the PSG; reflects area background	8 detects - maximum @ MW-1 on 01/14/97: 0.31 pCi/L.	No field screening for radionuclides.	24 detects: maximum @ MW-03 (dup) on 10/18/96: 1.88 pCi/L.
Arsenic	5	µg/L	N	Suspected anomalous data: 1 low level detect occurred in the first sample collected at MW-5 but has not been repeated.	Not detected.	No field screening for metals.	1 detect: @ MW-05 on 12/17/96: 6 µg/L.
Copper	1000	µg/L	N	No occurrences above the PSG; reflects area background.	3 detects - maximum @ MW-1 on 07/11/97: 19 µg/L.	No field screening for metals.	5 detects: maximum @ MW-02 on 04/10/97: 20 µg/L.
Nickel	100	µg/L	N	No occurrences above the PSG; reflects area background.	4 detects - maximum @ MW-1 on 04/11/97: 13 µg/L.	No field screening for metals.	20 detects: @ MW-02 on 01/05/97: 20 µg/L.
Zinc	5000	µg/L	N	No occurrences above the PSG; reflects area background.	2 detects - maximum @ MW-1& BS-004PZ on 01/04/97: 61 µg/L.	No field screening for metals.	3 detects: @ MW-04 on 01/1497: 270 µg/L.

Note: Number of detects includes those associated with primary samples only; duplicate samples are not included in this number.

Note: For the radionuclides, the number of detects does not include negative values.

Note: Monitoring wells were sampled during a total of 4 or 5 groundwater monitoring events, depending on the date of installation:
Wells installed as part of the PA/SI (BS-004PZ through BS-006PZ) were sampled 4 times (9/17/96, 01/14-15/97, 04/9-11/97, and 07/10-11/97).
Wells installed as part of the RI (MW-1 through MW-5) were sampled 5 times (10/15-18/96, 12/17/96, 01/14-15/97, 04/9-11/97, and 07/10-11/97).

COC = Contaminant of concern
ft bgs = Feet below ground surface
pCi/L = PicoCuries per liter
PSG = Project screening goal
SVOC = Semivolatile organic compound
TPH = Total petroleum hydrocarbons
VOC = Volatile organic compound
µg/L = Micrograms per liter
MTCA = Washington State Model Toxics Control Act
MCL = Maximum Contaminant Level